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DIGITAL VOLTMETER
LM 1620

SOLARTRON

TECHNICAL MANUAL

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DIGITAL VOLTMETER LM1620



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differential input at a negative potential. The output will therefore swing rapidly positive until diode MRA conducts, making the amplifier configuration a closed-loop with capacitive feedback. (fig. 3.4b). The final output voltage will now be the product of the input voltage and the capacitance ratio of C_b to C_c plus the initial charge on C_c , and is a linear function of the input signal. The amplifier differential input returns to the original offset level and the charge transfer from C_b to C_c is completed during a 10 millisecond settling period obtained by gating the clock oscillator with the 2000 bistable output. The return of this bistable to the 2000 state is inhibited by an output from relay D driver during the period that relay D contact is open. A small delay is included so that at the time that relay D contact closes and the counter reset pulse is generated the 2000 bistable remains inhibited. Thus the counter registers 3000. The count continues for a further 1000 pulses to enable the charge transfer to complete, as previously described, and the counter registers zero (4000). The forward bias on diode MRB derived from the 2000 bistable is thus removed and reference current applied to the differential input via diode MRC. Capacitor C_c now discharges at a rate determined by the reference current source and the amplifier produces a linear output ramp-down until MRA ceases to conduct. (fig. 3.4c). The amplifier, operating once more in the open-loop configuration, produces a rapid transition through zero causing the detector to give an output which closes the

clock gate and operates the display unblanking circuitry. The various factors described effecting the conversion of the D. C. input signal to the time period of the output ramp are constants and therefore it can be stated that the ramp-down period is directly proportional to the input signal. By stopping the counter with the detector output at the end of the ramp-down a direct reading of the magnitude of the input signal is displayed on operation of the display unblanking.

1999 Gate: With an input signal in excess of full-scale on the range in use a count of 1999 will be reached before ramp-down is complete. In this condition the seven input AND gate produces an output which is fed to the detector and thus the clock gate is closed. 1999 will be continually digitised until the voltmeter is up-ranged.

Polarity Change: When the input signal changes sign an initial positive potential will be applied to the amplifier input causing the output to swing negative. The detector will produce an output and thus the gate between the 2000 bistable and the polarity bistable is opened at the instant when reference current is switched (when the 2000 bistable changes state) and the polarity bistable is thereby triggered. The polarity bistable outputs feed the drive circuitry to illuminate the appropriate neon polarity indicator and this circuit is also used to steer the relay A and B driver such that the necessary changeover takes place to ensure a negative input to the amplifier on the succeeding sample. For the duration of a polarity reversal routine the display registers zero (000).

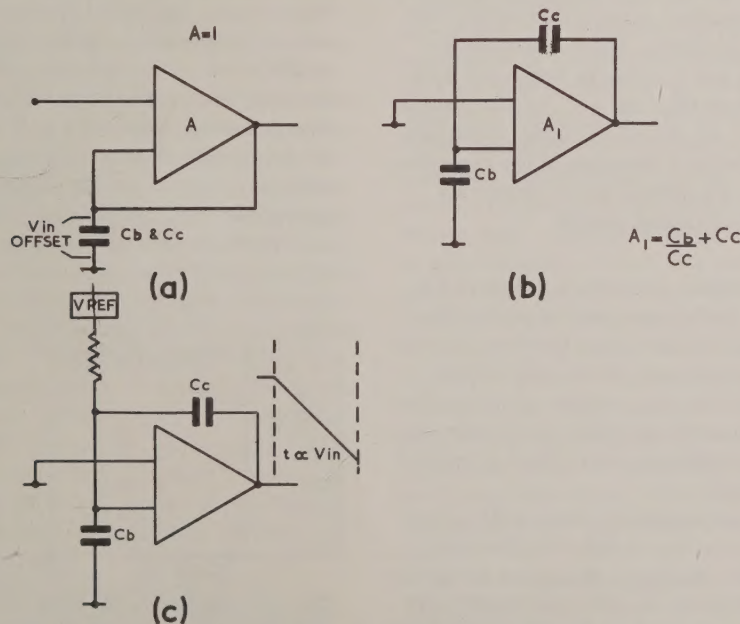


Fig. 3.4 Simplified Amplifier Configurations.

SECTION 4

CIRCUIT DESCRIPTION

Introduction

This description refers to circuit diagrams sheets 1 and 2 at the rear of the manual. Reference will also be made to the Simplified Block Diagram and the Operational Waveforms (Section 3 Figs. 3, 2 and 3,3). It should be appreciated that the waveforms of fig.3, 3 are simplified to clearly show the principles of operation. Actual waveform photographs are shown in fig 5, 5.

The various circuit functions will be more readily understood if an assessment of some of the design principles is first made.

The LM1620 Digital Voltmeter is a high-performance instrument of compact size and competitive price. Attention is given to simplicity of operation with a minimum of setting-up before use. This has been achieved by the complete elimination of zero drift resulting in a need for only one front-panel preset calibration control. For industrial and systems applications rejection of common mode interference is an important feature and to this end the input terminals are maintained fully-floating.

The full-scale reading of 1999 has been chosen to provide the most favourable range changeover point and hence excellent overall accuracy.

The input resistance quoted for the two basic ranges is defined by the combined leakage resistance of the input terminals, switching, input capacitors and associated wiring and will thus be dependent upon humidity and temperature but will remain in excess of 1000M Ω under all normal operating conditions. It should be appreciated that none of the capacitors, including C4, at the input of the voltmeter are discharged by the digitising process.

Circuit Notes

The LM1620 voltmeter circuitry is conveniently divided into two distinct sections; input amplifier and logic section (Printed Circuit Board 2); Counter, decode and numerical indicator drivers (Printed Circuit Board 1). The power supply unit components and the input attenuator and filter components are mounted on two additional printed circuits boards 4 and 3 respectively.

Board mounted components are shown enclosed by chain-dotted lines on the circuit diagrams and appear in the parts lists below the appropriate printed circuit board reference. All other components are chassis mounted and appear in the parts list headed "Main Assembly".

Interconnections

All printed circuit board interconnections are made with direct wiring. The interconnection pins of printed circuit board 2 (circuit diagram Sheet 1) are identified by numbers adjacent to the pins on the printed board and corresponding numbers on the circuit diagram. The output and interconnecting points of printed circuit board 1 are all brought out to the pads of a 42-way printed circuit board edge-connector comb and thus the number and letter symbols on sheet 2 of the circuit diagram refer to this comb, as shown on the inset sketch.

Edge-connector outputs are listed under the heading "Print Out Information" (Section 1 Page 1, 2).

Circuit Description

Input Attenuator, Filter and Range Switch:

The input attenuator and filter are contained in a screening box, isolated from the earth referenced input amplifier by the action of relays RLA, RLB, RLE, and the storage capacitor C4. The screening box is connected to the instrument chassis earth via filter capacitor C7 and resistor R6 which define the input isolation between terminals LO and EARTH as 200M Ω shunted by 1000pF.

Range switch (SA) selects combinations of the two values of attenuation together with two values of amplifier reference current to provide five ranges as shown in Table 4. 1. Switch wafers SA3F/SA4F select the attenuation value and switch wafers SA1F/SA2F the appropriate value of reference current. Switch wafer SA1F also selects the decimal point indicator appropriate to the range in use. The remaining contacts of switch wafer SA2F are available for the optional addition of range output information (details of this modification are included in Addendum 1 at the rear of the manual).

RANGE	ATTENUATION	INPUT IMPEDANCE	REF. I VALUE
200mV	0	> 1000M Ω	X1
2V	0		X10
20V	X100	10M Ω	X1
200V	X100		X10
1KV	X1000		X10

Table 4.1 INPUT RANGING

The sixth position of the range switch opens input HI and applies the saturated reference cell BY1 to the input providing a self-calibrating facility.

Overload Protection:

The input circuitry of the digital voltmeter is not easily damaged by voltage overloads, but neon V1 and series limiting resistor R4 are included to extend the overload limits to the specified values of 350V on ranges 1 and 2 and up to 1000V on ranges 3, 4 and 5. Resistor R32 limits the input grid current of double-triode V1 under these conditions.

Filter:

Components R4/R6/R7/C1/C2 and C4 (RLE closed) form a permanently connected filter to provide 40dB of series mode rejection at 45Hz, increasing at 12dB per octave at higher frequencies.

Input Amplifier:

Double triode V1 forms the input stage to a virtual-earth differential amplifier. The grid at pin 7 of V1 will be referred to as the signal input and the grid at pin 2 the differential input or virtual earth. In order to achieve optimum linearity over a comparatively wide range of input signal amplitudes the stage is fed such that the anode to cathode voltage of the two triodes is held constant and the junction of their cathode loads is taken to a constant-current stage.

Transistor VT11 feeds resistor R42 with constant current thus defining a constant cathode to anode voltage for the two halves of V1. The anode current of V1 is isolated from VT11 by the emitter follower VT13. Transistor VT12 forms a second constant current source, the difference between the two constant currents providing the anode current to V1. Additional stability is achieved by feeding the stage from the +90V reference supply.

Resulting from the charge-transfer technique used in the input circuitry the amplifier input impedance is effectively multiplied by the mark/space ratio of the input relay chopping cycle, by an approximate factor of 25 at the input terminals of the voltmeter. Input error currents are reduced by the same factor. However, it is still necessary that the input amplifier should have a high input impedance and a low grid current, both of which are achieved by operating the input triodes under electrometer conditions.

The outputs at the cathodes of V1 drive three direct-coupled, common-emitter, differential amplifiers with a total open-loop gain of approximately one million. Zener diode MR18 is included to stabilise transistor stage VT16/VT17 against mains-derived power-rail fluctuations. Components C16/R13, connected between the collectors of transistors VT19/VT21, define the AC response of the amplifier, providing sufficient roll-off to prevent H. F. oscillation. Transistors VT25/VT26 form the

output stage. The collector of VT26 is grounded and a single-ended output taken from the collector of VT25. It should be noted that the output at VT25 collector will be in-phase with the signal input and in reverse-phase with the differential input.

Amplifier Feedback and Charge Networks:

From the Technical Description of Section 3 it was shown that the relays operate such that a negative input is applied to the amplifier signal input at the time that relay RLC is closed. Since there is 100% feed-back to the differential input, the final gain of the amplifier is unity. Thus the amplifier output rapidly charges the three parallel connected capacitors C18/C19/C20 to the value of the input voltage. Incidentally, capacitor C22 also charges to this level via transistor VT23, diode MR25 being reverse-biased at this time. In practice there is always a small offset voltage between the two amplifier inputs due to amplifier unbalance, but, since this offset is constant during the period of the measurement and the amplifier inputs return to this level at the conclusion of the charge transfer function, the offset voltage will not be superimposed on the final ramp.

Capacitors C18/C19/C20 and C22 thus become fully charged to the value of the negative input signal, plus offset, and the next action is that contacts RLC/1 open and contacts RLD/1 close to zero volts via resistor R29.

The amplifier output swings rapidly positive and forward biases diode MR25 to close the loop with capacitive feedback, via C22. The gain of the amplifier is now defined by the ratio of input capacitance to feedback capacitance, approximately 20:1 and thus the final charge on C22 represents this figure plus the initial charge on C22. Transistor VT23, base referenced by zener diode MR20, forms a constant-current stage, limited by emitter resistor R91 to a maximum of 500 microamps. This constant current stage, together with diode MR25, provides an approximately +6 volts bias level to ensure precise feedback switching levels at the commencement of the charge period and at the conclusion of the ramp. The bias level is short-term stable for the period between the feedback switching points and its effect on the duration of the output ramp is therefore negligible. Transistor VT28 forms an emitter switch to convert any negative excursion at the amplifier output, via diode MR28, into a suitable negative edge to drive detector transistor VT20.

+ 90 Volts Reference Supply:

This supply is derived from the +250V rail via dropping resistor R4 and is shunt-stabilised by transistor VT27.

The reference divider chain, including neon stabiliser V2 is fed with constant current by the action of transistor VT27 and zener diode MR29. The reference voltage is thus stabilised against power rail fluctuations. The two values of reference current obtained from this supply are defined by resistors R90 and R92 and are in the region of 10 and 100 microamps respectively. The precise values are set during calibration using the three preset controls.

Reference Current Switching:

Reference current is switched to the amplifier virtual earth, during the ramp-down period, via diode MR22. Prior to the ramp-down, reference current is diverted via diodes MR23/MR24 which are forward biased by the negative output from the "2000" bistable. At the conclusion of the ramp-down, reference current is again diverted, this time via MR23/MR26 forward biased by the amplifier output negative excursion. This later function (removing the reference current on the negative excursion), prevents the amplifier reaching a saturated end-stop condition. Diode MR27 limits the maximum positive amplifier output excursion during the charge transfer period by clamping the output to the +70V rail. The collector voltage of transistor VT25 could otherwise rise to +250V under conditions of input overload, thereby exceeding its breakdown-voltage.

L.F. Multivibrator:

Transistors VT6/VT8 form an emitter-coupled multivibrator to supply the drive waveform to operate the reed relay circuitry.

With mode switch (SB) at AUTO the circuit free-runs and produces negative-going pulses 20 milliseconds wide at an approximate repetition rate of two pulses per second.

Two outputs are taken from the emitter of transistor VT8, one to drive the base of relay RLC driver transistor VT9, and the other to drive the base of transistor VT4, the driver for relay RLA or relay RLB depending on the states of transistors VT3 and VT5. Components C12, MR12 and R40 form a network to delay the drive to transistor VT4 by approximately 700 microseconds. This ensures that relay RLC operates in advance of the remaining relays. The multivibrator circuit time-constants are defined by capacitor C5, the long time constant resistor R26 and the short time constant resistor R23.

Diode switching ensures a fast rise and fall to the output waveform and eliminates timing-errors produced by transistor leakage-current. Consider transistor VT6 to be in the high-current state and transistor VT8 in the low-current state with diode MR9 reverse-biased. Transistor VT6 is

fed via resistor R23, diode MR8 and resistor R22 such that in the high current state, the collector voltage will be approximately at +6V. The base of transistor VT8, closely followed by its emitter, is connected to the collector of transistor VT6 and thus the output waveform rests at this level. Capacitor C5 commences to charge via the long time-constant resistor R26 and contributes current, via diode MR8, to that already flowing in transistor VT6. The charge continues until the potential at diode MR9 anode rises above +6V. Diode MR9 conducts to reduce VT6 collector current, thus causing the collector voltage to move negatively. Transistor VT8 is driven further into conduction and an accumulative positive feedback condition results producing a rapid negative going output edge at the emitter of transistor VT8. This edge is transferred instantaneously via diode MR9 and capacitor C5 to the anode of diode MR8 which is thereby reverse-biased. Transistor VT6 is thus switched to the low current state, with its emitter current defined by R21 at approximately 50 microamps and its collector voltage at approximately -11 volts. The base of VT8, closely followed by the emitter, is connected to the collector of transistor VT6 and thus the output waveform rests at approximately -10.5 volts. Capacitor C5 commences to charge via the short time-constant resistor R23, diode MR9 and transistor VT8, until the potential at the anode of diode MR8 exceeds +12V. The diode then conducts and current is diverted via the collector current of transistor VT6. The accumulative feedback action again takes place until transistor VT8 is again in the low-current state with diode MR9 reverse-biased and transistor VT6 rests in the high-current state with the emitter output at approximately +6V for the duration of the long time-constant.

Manual Operation:

When the mode switch (SB) is set to MANUAL the anode of diode MR9 is held at approximately +2 volts by resistor R16 connected to the zero volts rail. The charge on capacitor C5 via resistor R26 is now unable to rise to the +6 volts level necessary to forward-bias diode MR9 and thus the circuit holds in the long time constant state. Operation of SAMPLE button (SC), applies an instantaneous negative edge, via resistor R27 and capacitors C6 and C5, to diode MR8 anode initiating the short time-constant sequence. The output is thus a single negative pulse following each operation of the SAMPLE button.

Polarity Bistable and Relay Drive Circuitry:

Transistors VT1/VT2 form a conventional bistable circuit. Initially the bistable will switch to one of

the two possible states, determined by circuit constants, -and may then be reset by an output from the 2000 bistable, gated by detector transistor VT20 if an incorrect polarity is sensed. The 2000 bistable output is taken to the junction of resistor R82 and capacitor C21. The reset line to the polarity bistable is taken from the junction of C21 and R81 and fed to the gating diode MR1. Resistor R8 holds the cathode of MR1 to 0 volts. Should the detector output be at 0 volts at the time that the 2000 bistable switches to the 2000 state the positive going edge, differentiated by C21 will pass via diode MR1, capacitors C1/C2 and the appropriate steering diode MR2 or MR4 to cut-off the previously conducting transistor and thus switch the bistable to the correct polarity state. The collector output from the "on" transistor is then fed to operate the appropriate relay switching and polarity indicator drive transistor VT3 or VT5. Diodes MR6/MR7 isolate the two relay coils from the "off" neon. The relay driver is transistor VT4, driven on its base by the delayed output of the L.F. Multivibrator. Assuming a negative input to the instrument, transistor VT2 will be conducting with its collector at approximately 0 volts. The output from the junction of resistors R14/R15 will thus be at approximately -9.5 volts and transistor VT5 will conduct, illuminating the negative polarity indicator neon ILP2. When transistor VT4 receives the negative edge from the multivibrator on its base, diode MR7 is forward biased and relay RLB will operate closing contacts RLB/1 and RLB/2. Contacts RLE/1, RLE/2 and RLD/1 are required to open at the time that contacts RLA or RLB close and therefore transistor VT14 is made to be normally conducting, by virtue of bias network R46/R47/R48 and is switched off by the collector output of VT4 via diode MR14. Diode MR15 is included to prevent the mutual damping effect of the parallel inductances of the relay coils during switch-off. Transistor VT9 drives relay C from the direct output of the multivibrator.

Counter Reset:

The positive edge produced at the collector of driver transistor VT14 to close the contacts of relays RLD and RLE is fed via diode MR17 and capacitor C14 to the base of transistor VT18. The collector output of VT18, a -10 volt pulse, is fed to the right-hand transistors of the units, tens, and hundreds bistables and to the left-hand transistor of the 1000 bistable. The counters are thus reset to 1000.

Detector:

The function of transistor VT20 is to sense a negative output from the amplifier, 1999 gate or L. F. multivibrator.

It would appear that VT20 is normally conducting due to forward bias from divider R68/R69/R70. However, under normal circumstances, the junction of resistors R69/R70 is held at 0 volts by one or more of the seven diodes connected to the 1999 gate line. The base of VT20 is thus held at approximately +3V and the transistor thereby held off. There are now three possible conditions which will produce an output from VT20: The anodes of all seven 1999 gate diodes at -12V (1999 digitised); amplifier output negative; negative pulse-period of L. F. Multivibrator.

The detector circuit therefore appears as a logical NOR function, using negative logic ($0 = 0V/1 = -12V$), any one of three inputs at 1 producing a 0 output. The detector output provides one of the inputs to buffer stage VT22 and also, via resistors R80/R81, applies forward bias to diode MR1 to enable the polarity bistable to be reset by the 2000 bistable if the input signal changes sign.

Buffer:

Transistor VT22 is the active element for a further NOR Circuit. Normally held off by the positive potential at its base via resistor R78, the transistor may be turned on by either of the two inputs, at the junction of R79/R82, being at -12 volts (logical 1). The collector will then be at 0 volts (logical 0) and this output is fed, via resistor R89, to open the steering-diodes MR1/MR2 of the first bistable of the units counter to allow the passage of clock pulses.

The condition at which clock pulses will not be fed to the counter is when both inputs are at 0 volts, which requires a "1" input to the detector and the 2000 bistable to be in the 2000 state.

Display Blanking:

For the duration of the period that pulses are fed to the counter the display is blanked. When the collector of buffer transistor VT22 moves from -12 to 0 volts, the condition where pulses are gated to the counter, the base of blanking transistor VT24 moves to a level of approximately +4 volts via resistor R88 and since VT24 is an NPN transistor it is thereby turned on. The collector of VT24 is connected to the anodes of the three blanking diodes MR34/MR35/MR36 and the anodes of the three numerical indicator tubes V1/V2/V3 are thereby taken to 0 volts and the display extinguished. The "1000" indicator neon lamp LP6 is blanked in a similar manner, via diode MR40.

Clock Oscillator:

The pulses generated by this oscillator are gated by

an output from buffer transistor VT22 and totalised in the display counter.

A series resonant-mode crystal-controlled oscillator (VT7) is employed, transformer T1 providing sufficient positive feedback to cause clipping. The output is thus in the form of pulses suitable to drive the first bistable of the units counter. The output, via capacitor C8, is superimposed on a D.C. level obtained from the collector of buffer transistor VT22 via resistor R89 and is then fed to steering diodes MR1/MR2 of the units counter (Circuit Diagram Sheet 2). Provided that VT22 collector is at 0 volts, pulses will be free to pass via the steering diodes to the units counter. A negative output at VT22 collector will hold both steering-diodes reverse-biased thus preventing further totalisation.

2000 Bistable:

The 2000 bistable, transistors VT10/VT15, is so named because it accepts the carry pulse from the output of the 1000 bistable (Transistors VT55/VT56 circuit diagram sheet 2). Its functions are, however, confined to switching logic and it does not contribute to the display (1999 full-scale).

The positive going carry pulse from the collector of the right-hand transistor of the 1000 bistable is applied to the base of transistor VT10 (2000 side) via capacitor C11 and diode MR13. To ensure that the 2000 bistable is not reset to the 2000 state before the time that reference current is switched, an inhibit, in the form of reverse-bias, is applied to the anode of diode MR13. This negative potential is obtained from the -12 volt rail via resistors R59/R56/R104 and is released by the collector of transistor VT14 moving to zero volts thus forward biasing MR17 at the time that relays RLD/RLE close. Capacitor C26 delays this moment of release by approximately 30 microseconds to ensure that the counter reset pulse, generated by transistor VT18, has completed. The 2000 set line conveys the positive edge from the L.F. Multivibrator, via capacitor C13 and steering diode MR16, to the base of transistor VT15.

The output from the 2000 side of the bistable, at VT15 collector, applies the bias to diode MR24 via resistor R93 to switch the reference current to the amplifier virtual earth. This same output provides one of the OR functions to the input of buffer transistor VT22 at the junction of R82/C21 and also, via C21, provides the positive edge to trip the polarity bistable if diode MR1 is forward biased by a "0" output from the detector via resistors R80/R81.

Display Counter:

Three four-bistable, binary decade counters are

employed for the hundreds, tens and units stages, and a single bistable one-count circuit for the one-thousand stage.

The units (first decade) counter is driven directly from the 100KHz clock oscillator. All decade counters are scaled to a count of ten by means of a diode trigger pulse gating system. The outputs from the three decade counters are fed to resistive networks for decoding from BCD to decimal form. Switching of the numerical indicator tubes is by transistor drive stages.

First Decade Counter and Decode Circuit:

The input signal, in the form of a 6 volts amplitude pulse train, is taken from the collector of clock oscillator transistor VT7 via capacitor C8 and superimposed on the gating level from the collector of VT22. The counter employs transistors VT2/VT3, VT6/VT8, VT10/VT13, VT15/VT18 connected in four symmetrical bistable circuits.

Each bistable, except VT2/VT3, is provided with steering diodes and trigger capacitors (MR4/MR6, C5/C6 in the second bistable), to ensure that the positive triggering edge is applied to the base of the conducting transistor. In the first bistable, trigger capacitors are not included since the gating level is to be directly applied to the anodes of steering diodes MR1/MR2. At the commencement of each digitisation period, a negative reset pulse is generated by reset driver transistor VT18 and taken to the pin connected to edge connector pad 12. This reset pulse is applied to the 1, 2, 4 and 8 sides VT3, VT8, VT13 and VT18) of the bistables to turn on these transistors, and thus set the counter to the zero register condition in readiness for the impending count. The pulses counted progress through the stages in a conventional sequence up to the eighth pulse. During this period the positive triggering pulses from the collector of VT3 are passed to the base of VT8 via gating diode MR5, which is held in the forward-biased condition by the -12 volts potential present at the collector of the "off" transistor VT15. On receipt of the eighth pulse, the fourth stage bistable is switched to the "8" (VT15 conducting) condition and all other stages are set to the "I" condition (VT3, VT8, VT13 conducting). As a result of VT15 collector going from -12 to zero volts, the forward bias is removed from MR5, and any output pulses appearing at VT3 collector are prevented from reaching the base of VT8. Thus the second (2) and the third (4) stages are inhibited from operation after the eighth pulse. The ninth pulse will therefore switch the first stage to the "1" condition (VT2 conducting) to effect a count of nine (8 + 1). Finally, the positive output

pulse from the first stage initiated by the tenth pulse is gated to bypass the second and third stages and switch the fourth stage to "8" (VT18 conducting) via C9 and MR9. Thus the counter is returned to zero, and the positive step developed at the collector of VT18 when that transistor is cut-on, provides the drive to the succeeding decade counter. The method of decoding employed makes use of the fact that if the first stage bistable (1) is at "1" the numeral to be displayed must be an odd number. Conversely, if the "1" bistable is at "1" the displayed numeral must be an even number. Accordingly, the circuit is designed to inhibit the operation of the transistor switches controlling the even or odd cathodes of the indicator tube having regard to the condition of the first stage bistable. The selection of the appropriate numeral from the non-inhibited numerals is then performed by a series of resistor gates monitoring the output of the second (2), third (4), and fourth (8) stage bistables. Assume that the decade counter registers a count of nine (1 $\overline{2}$ 48). Since the first stage bistable is at "1" (VT2 conducting), the common emitter rail of the transistor (VT4, VT7, VT11, VT14 and VT17), switching the odd numerals will be held at approximately -1.5 volts by the voltage drop developed across VT2 emitter-resistor R5. Furthermore, the common-emitter rail of the transistors (VT1, VT5, VT9, VT12 and VT16) controlling the zero and even numerals will be held at a potential of approximately zero volts by the emitter resistor of the "off" transistor VT3. Thus, when the common base rail of a pair of transistors (i.e. VT1/VT4, VT5/VT7 etc) is taken positive, the odd-numeral switching transistors (VT4, VT7 etc) will conduct first by virtue of the 1.5 volts negative bias at their emitters. The base potentials of the transistor pairs are determined by the outputs (-12 or zero volts) from the counting bistables applied via a series of resistor gates. The common base potential of any transistor pair having one or more -12 volt inputs on the associated gate line or lines, will be held negative and both transistors will be cut-off. Conversely, the common base potential of any transistor pair having no -12 volt signals on any gate input, will stand positive, and that transistor whose common emitter rail is at -1.5 volts will conduct. In the present example which assumed that the counter was set for a count of nine, the bistable outputs will be as listed:-

1	-12V	4	0V
$\overline{1}$	0V	$\overline{4}$	-12V
2	0V	8	-12V
$\overline{2}$	-12V	$\overline{8}$	0V

It can be seen from the circuit diagram that in these circumstances the only pair of transistors whose common base potential can go positive is VT16/VT17. Since the emitter potential of VT17 is 1.5 volts more negative than that of VT16, the former transistor will conduct first, thereby taking the common base potential to approximately -1 volt, and thus holding VT16 "off". The collector of VT17 is connected directly to the "9" indicator cathode (pin 11, V1) of the number tube enabling the neon to strike and display the number. The cathodes of all other numerals are connected to the collectors of the non-conducting transistors (VT1, VT4, VT5, VT7, VT9, VT11, VT12, VT14 and VT16) and are thus held, unable to strike.

Second and Third Decade Counters and Decode Circuits:

The counter and decode circuits for the tens and hundreds Counters are identical with that of the units counter except that triggering capacitors are included on each counter input stage (C11/C14 and C21/C24).

1000 Bistable:

A single bistable circuit VT55/VT56 is provided to make the "1000" count. The output from the collector of VT55 drives the base of VT57 to switch the "1000" indicator neon ILP6 (located on Circuit Diagram Sheet 1).

1999 Gate:

The outputs from the 1, 8, 10, 80, 100, 800 and 1000 sides of the bistable counters are taken to the "1999" line via diodes MR3, MR11, MR14, MR22, MR25, MR33 and MR39 respectively. When the instrument reaches a reading of "1999", the anodes of all diodes will stand at -12 volts forward biasing detector transistor VT20 and thereby inhibiting the further application of clock pulses to the counter input through the action of buffer transistor VT22, thus preventing the counter from re-circulating to produce an invalid reading.

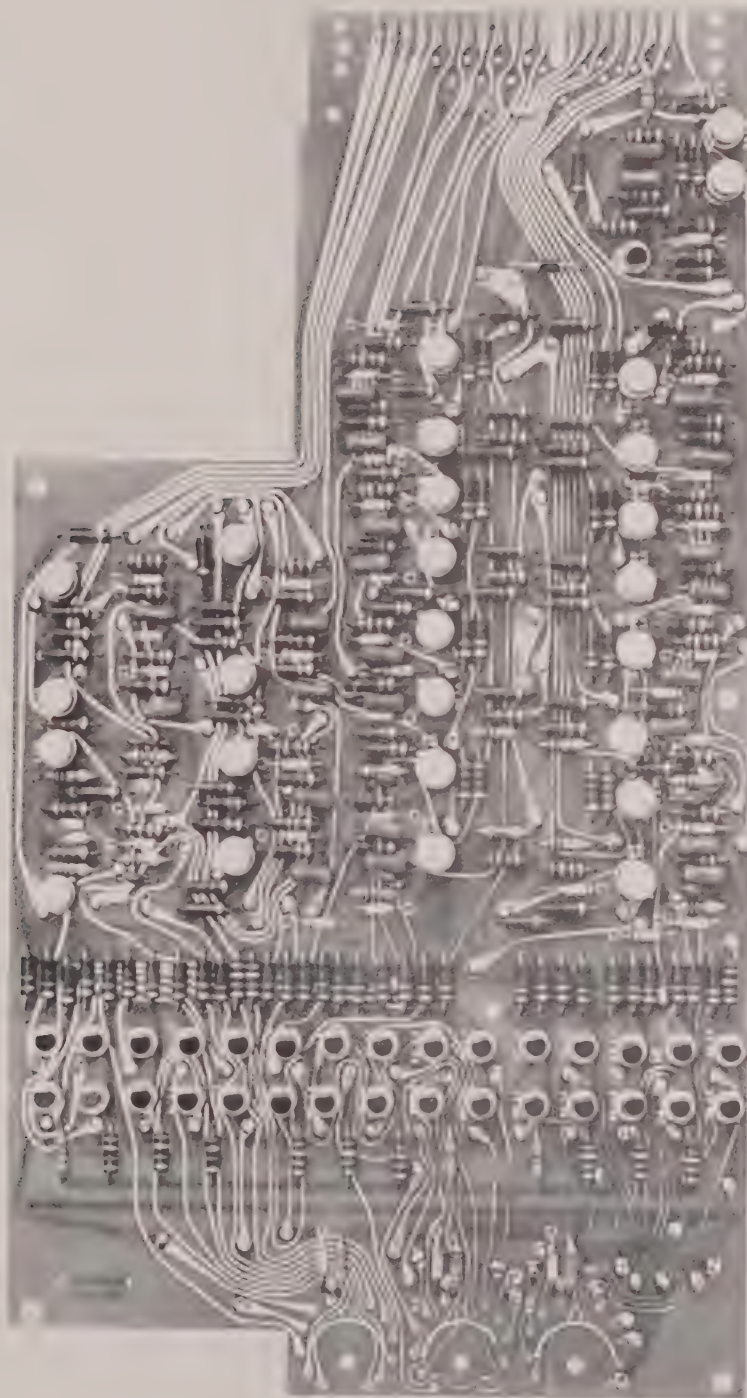
Power Supply Unit

General:

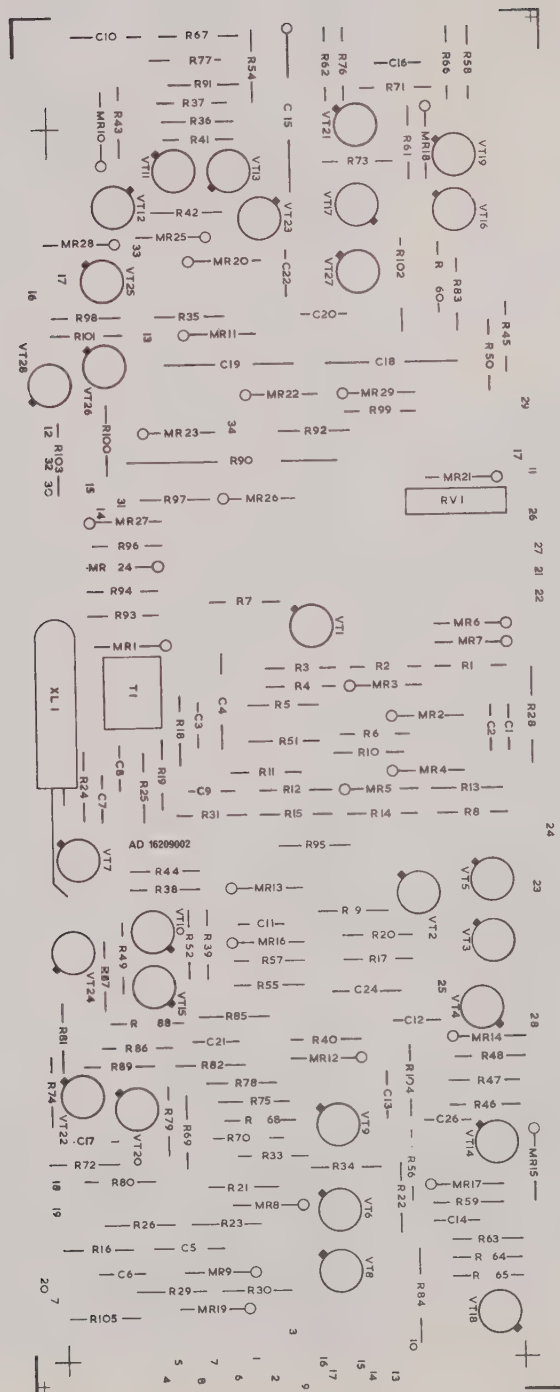
The unit comprises a mains transformer and a printed-circuit board carrying the rectifying components.

Mains Input Circuit:

The mains transformer T1 is provided with a split primary winding capable of parallel or series connection to accommodate mains inputs within the



Counter Board Assembly Component Layout PCB No. 1.



Amplifier Board Assembly Component Location PCB No. 2.

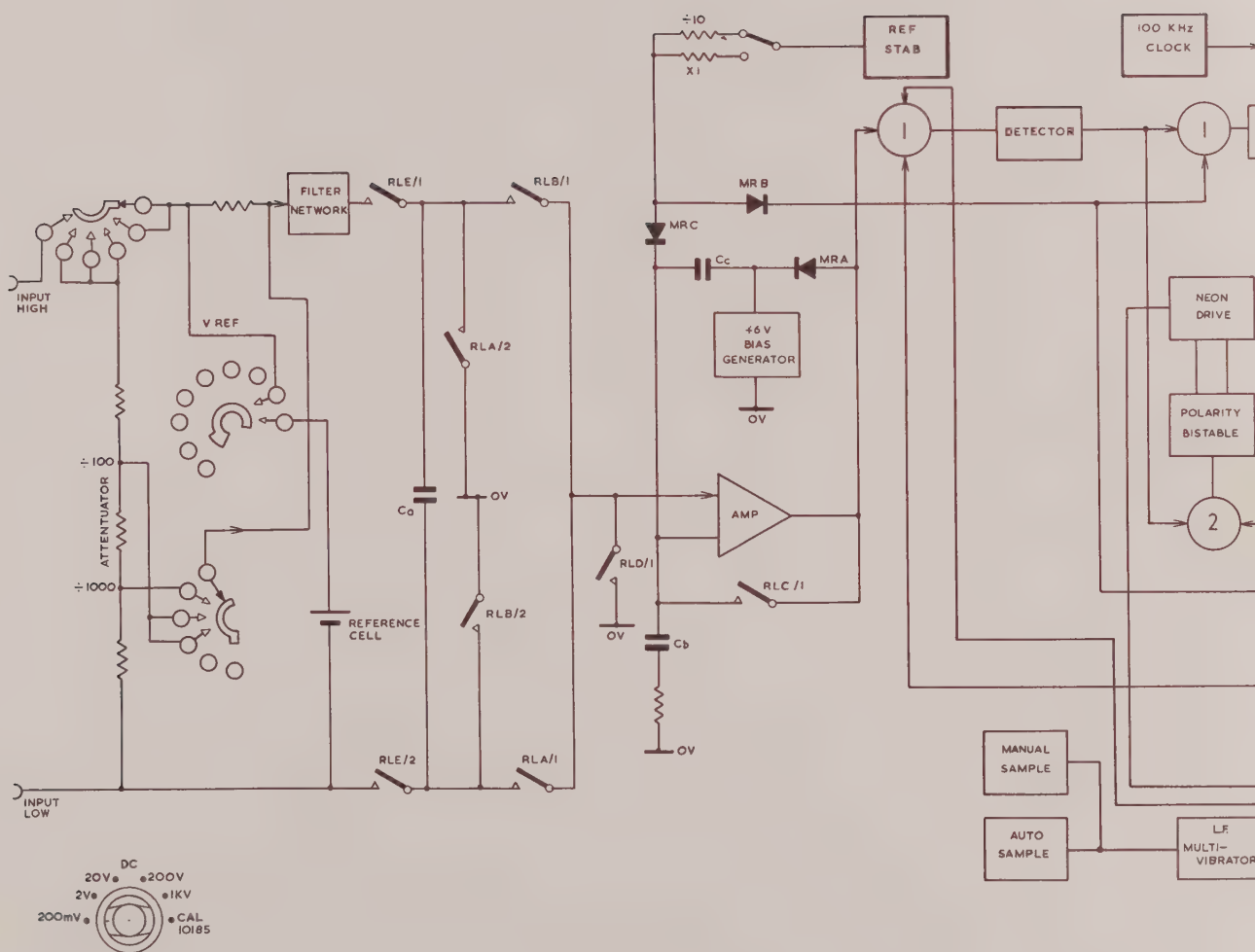


Fig. 3.2 Simplified Block



SECTION 5

MAINTENANCE

The procedure described in the following paragraphs is basically the production test to which all LM1620 Digital Voltmeters are subjected prior to dispatch. It is given to enable the user to confirm the performance of the instrument and to make any necessary adjustments. A 30 minute warm-up period should be allowed before calibration.

Test Equipment: The following items of test equipment are required to carry out the procedure in its entirety. Type numbers of suitable Solartron instruments are given in brackets.

- 1) Avometer Model 8
- 2) Variac

- 3) Monitoring Oscilloscope (CD1400)
- 4) Kintel Voltage Standard 303B
- 5) L. F. Oscillator (CO546)
- 6) 20M Ω 1% Resistor

Case Removal: Access to the instrument is obtained by removing the four Phillips screws from the rear plastic retainers (see fig. 2, 1) and withdrawing the covers. To further improve accessibility the lower printed circuit board may be hinged outwards after removal of the T section front chassis support, held by two special extended screws, and the five board securing screws (see fig. 5, 1).

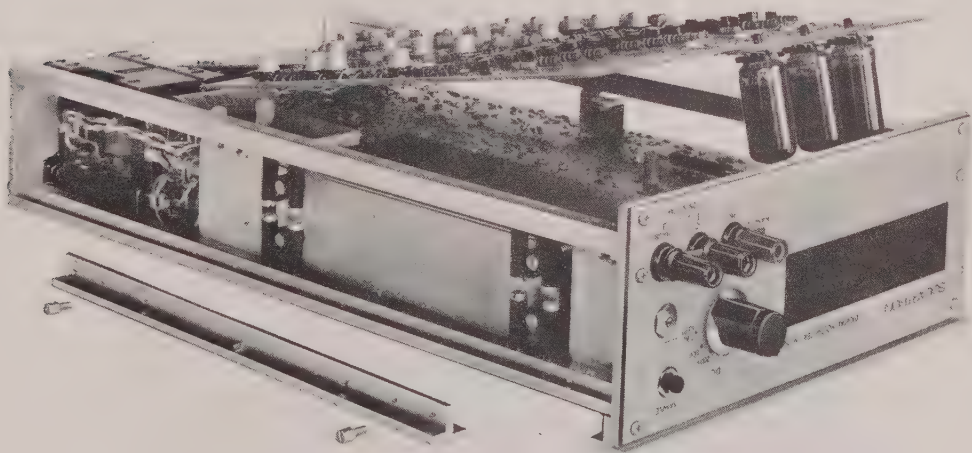


Fig. 5.1 Lower Board Access

Supply Rail Voltage Checks: (for location of the supply rails see Fig. 5.2) The supply rail voltages should be measured with the mains supply to the instrument set at the nominal voltage of 230V via the Variac, inputs HI, LO and CHASSIS shorted to-

gether and the mode switch at MANUAL. The voltages should be within the stated limits when measured with the Avometer with respect to zero volts. Ripple voltages are measured with the oscilloscope.

RAIL	LIMITS	RIPPLE
+250V	+250 $\pm$ 12.5V	<12V P/P
+90V*	+91.5 $\pm$ 2.5V	<50mV P/P
+70V	+70 $\pm$ 12.5V	<4V P/P
+12V	+12 $\pm$ 0.6V	<2V P/P
-12V	-12 $\pm$ 0.6V	<1.5V P/P

* NOTE: The stated limits for the +90V reference supply apply only with the front panel and internal preset CAL pots set fully clockwise. This measurement should therefore only be made if re-calibration of the instrument is anticipated.

Zero Check: With terminals HI, LO and CHASSIS shorted, select AUTO mode and check that zero is displayed on all positions of the range switch except CAL.

With LO and CHASSIS linked and the range selector at 200mV apply an input of less than 150 μ V from the voltage standard (item 4 of Test Equipment). Slowly increase the input level and check that the instrument begins to display 0002 within the range 150-250 μ V. Set range selector to 2V and check that the instrument displays zero. Increase the input level in 100 μ V steps and check that the instrument begins to display 0001 within the range 500-1200 μ V. Repeat with input polarity reversed.

Timing Check: With range selector to 2V apply an input of 1.8V and examine the amplifier output waveform (Test point B, Component Location 2) with the oscilloscope (TIME CM: 10ms/Y SENSITIVITY:

10 V/CM). Measure the period between relay D closing and reference current switching (TIME "C" fig. 3.3) and check that this is 10 $\pm$ 1mS.

Check MANUAL and AUTO Sampling:

With range selector at 2V and an input of 1.8V select MANUAL and note that the reading is held. Depress the SAMPLE button and check that one cycle of operation takes place.

Select AUTO mode and check that the number of samples taken during a period of 10 seconds is between 11 and 23.

Calibration of Basic Ranges (200mV and 2V):

With LO and CHASSIS linked and the range selector at 200mV, apply an input of 180mV from the voltage standard. Set front panel CAL pot to mid-range and adjust internal preset RV2 (located on power supply sub-chassis fig. 5.2) for a reading of 180.0.

Set range selector to 2V and apply an input of 1.8V. Adjust RV1 (located on PCB 2, adjacent to valve bracket) for a reading of 1.800. Repeat 200mV range adjustment.

Set range selector to CAL and check that the display reads midway between 1.018 and 1.019.

NOTE: Provided that the calibration source used for the previous steps has the required accuracy and the adjustments have been made as described, the reading obtained at this stage verifies the accuracy of the standard cell. (Expected E. M. F. decay <0.05% per year). (External check - see Component Location 3).

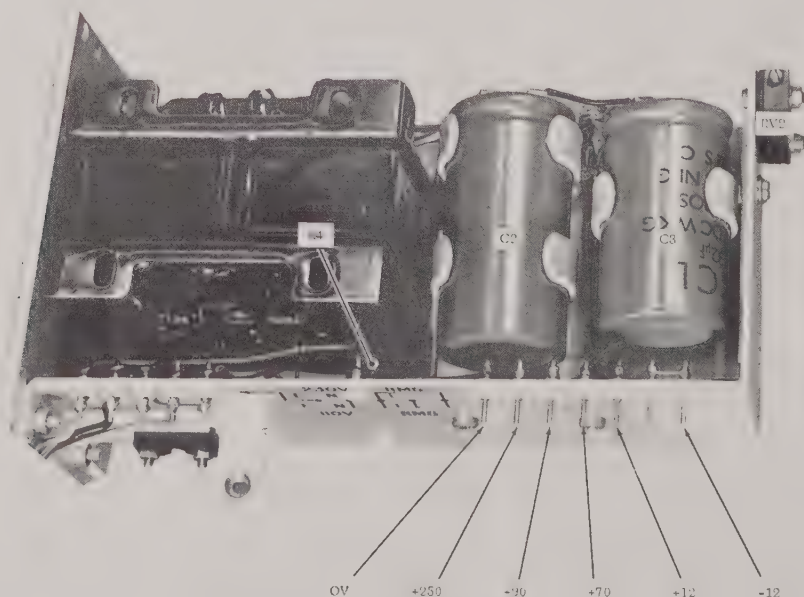


Fig. 5.2. Power Rail Locations

Circuit Diagram D16207001 (Sheet 1) - continued

C8 is added .001 in parallel with ILP6.

Circuit Diagram D16207001 (Sheet 2)

The line joining the emitter and collector of VT38 is deleted and redrawn to connect VT38 collector to the junction R127/pin R.

The following transistors are changed to A1778/2:

VT1, VT4, VT5, VT7, VT9, VT11, VT12, VT14, VT16, VT17, VT19, VT22, VT23, VT25, VT27, VT29, VT30, VT32, VT34, VT35, VT37, VT40, VT41, VT43, VT45, VT47, VT48, VT50, VT52, VT53

A 180K resistor is added between the collector, of each of the above transistors, and the +70V rail. The respective circuit references are as follows:

R1, R15, R16, R26, R29, R37, R42, R49, R52, R58, R64, R78, R80, R88, R93, R101, R106, R113, R116, R124, R128, R142, R144, R152, R157, R166, R170, R176, R178, R187

VT57 is A1778/2

SECTION 3

TECHNICAL DESCRIPTION

Basic Operational Principle

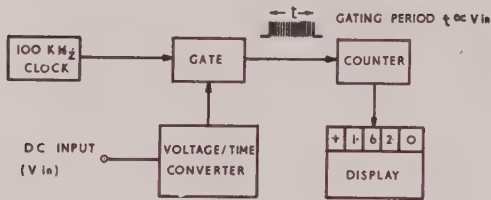


Fig. 3.1 Voltage/Time Converter.

The LM1620 Digital Voltmeter employs a digitisation technique whereby the gating period of a clock oscillator is varied, by means of a voltage-to-time converter, in direct proportion to the magnitude of the signal under measurement. The number of clock pulses passed during the gating period are totalised in a display counter.

The voltage-to-time converter is so calibrated that the total number of clock pulses, at the chosen frequency of 100kHz, gated to the counter and numerical display produce a direct reading of the magnitude of the input signal.

Voltage-to-time Converter

A simplified block diagram of the voltmeter is given in Fig. 3.2 and the operational waveforms are shown in Fig. 3.3.

Input Circuit: The signal to be measured is applied across terminals HI and LO. The HI terminal is the signal path and the LO terminal is floating internally but may be connected to earth externally. The range switch provides two direct inputs of 200mV and 2V full scale, three attenuated ranges of 20V, 200V and 1000V full scale and a CAL position where a standard reference cell is applied to the input. The input signal, suitably attenuated, passes via a filter and the reed relay choppers to the amplifier input.

The amplifier is designed to operate on a negative input and thus relays A and B are arranged as a

changeover switch and driven by polarity sensing circuitry such that a negative input is presented to the amplifier regardless of the polarity of signal applied to the input terminals. To maintain the input terminals fully floating, with consequent rejection of common mode signals, the contacts of relay E open as the contacts of the changeover relay (A or B) close. The action is break before make, which ensures complete isolation, and the input signal is stored on capacitor Ca.

Description of Operation: The following description assumes a negative signal applied to the input terminals. A polarity change will be separately described at the end of the section.

Input sampling is initiated by a multivibrator which on AUTO mode produces negative pulses 20 milliseconds in duration at a repetition frequency of approximately 2Hz to give two samples/sec. With the mode switch set to MANUAL a holdoff is applied to the multivibrator and a single pulse is produced following operation of the panel mounted SAMPLE button. This provides a single-shot facility.

At time A (fig.3.3) the negative edge from the multivibrator operates relay C, closing the loop between amplifier output and differential input. Relays E, D and B then operate such that the negative signal stored on Ca is applied to the amplifier input previously held at OV by the contact of relay D. Since relay C is closed the differential input is taken to a level compounded by the sum of the input signal and the amplifier offset voltage. Diode MRA is back-biased by virtue of the negative level at the amplifier output and the approximate +6V bias level at its cathode and thus capacitor Cc is effectively in parallel with capacitor Cb. These capacitors now charge to the input signal plus offset during the remainder of the 20 millisecond pulse period. (fig.3.4a).

At time B (fig. 3.3) the positive edge from the multivibrator resets the 2000 bistable to the 2000 state which applies a forward bias to diode MRB which in turn applies reverse bias to MRC. This removes the reference current supply, derived from a highly stable voltage reference source and a precision metal film current definition resistor. The contact of relay C opens and relay D contact closes to OV.

Since relay C is open and MRA is reverse biased the amplifier is now operating at high gain in an open-loop condition with the input closed to OV and the

Voltage Measurement

CAUTION

The maximum voltages that can safely be applied to the instrument are:-

200mV and 2V ranges $\pm 350V$
 20V, 200V and 1kV ranges $\pm 1000V$

With link removed:-

LO to CHASSIS $\pm 250V$ D.C. or peak A.C.

1. Set range selector to the appropriate input range. If the approximate value of the input voltage is not known set the range selector to 1000 Volts.
2. Connect signal lead to source of voltage to be measured, connecting the red terminal to signal high and the black terminal to signal low.
3. Set the mode selector to AUTO or MANUAL as required.
4. Read voltage from display, if necessary down-ranging to obtain greater accuracy. The graph of Fig. 2.7. demonstrates the advantages of down-

ranging. Although percentage of full-scale errors have been kept down to 0.05% (1 bit) it can be seen that measurements below 1/10 F. S. should be avoided by selecting a more sensitive range.

5. For normal measurements, where floating input is not required, the link should remain connected between terminals LO and CHASSIS.

NOTES:

a) If a reading of 1999 is obtained the instrument should be up-ranged. A display of 1999 is an overload condition, the display counter being staticised and not recirculated in the normal manner.

b) Measurements from very high source impedances may be made on the basic ranges (200mV and 2V). Accuracy is maintained with source impedances up to $10M\Omega$ provided that 1-2 minutes settling-time is allowed.

c) The effects of Series and Common Mode interference are discussed in Addendum 2.

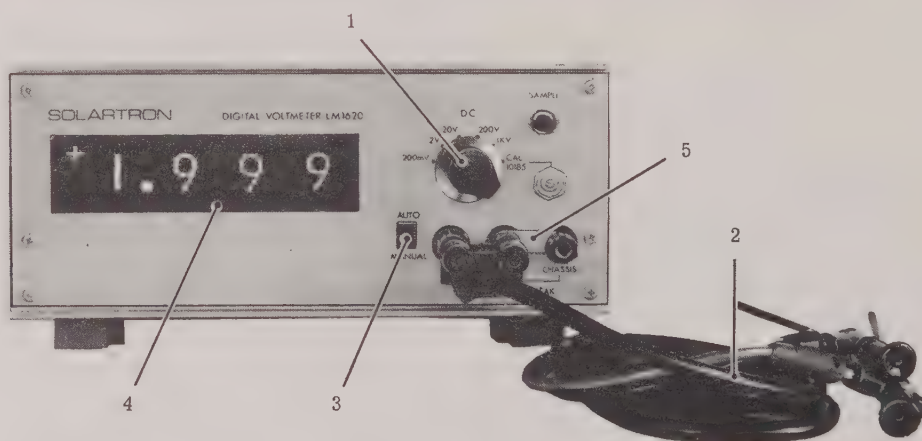


Fig. 2.6. Voltage Measurement.

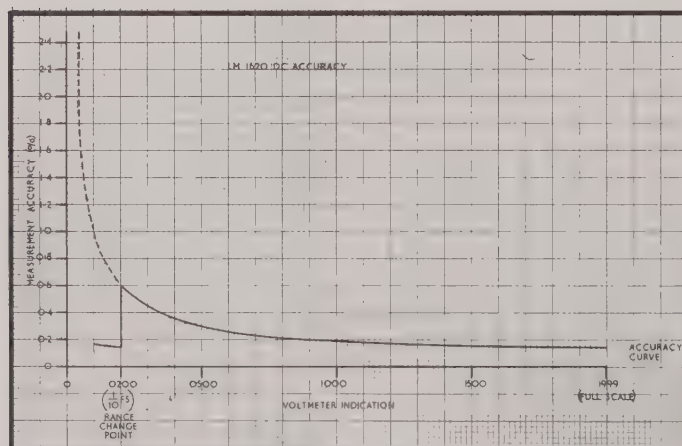


Fig. 2.7 Accuracy Graph.

Controls

1. **Range Switch:** A six position rotary switch giving a choice of 5 input ranges, 200mV, 2V, 20V, 200V and 1000V full scale, plus an internal calibrator position.
2. **CAL Control:** A preset screwdriver adjusted control enabling the instrument to be calibrated against its internal standard cell.
3. **AUTO/MANUAL Switch:** A two position slider switch giving the choice of two sampling modes: -
a) continuous sampling at a repetition rate of approximately two samples/second,
b) single shot operation initiated by the SAMPLE button.
4. **SAMPLE Button:** This push button is used in con-

junction with the AUTO/MANUAL switch. The button should not be pressed with the AUTO position selected as this may cause an erroneous reading. When the MANUAL position is selected the button will initiate one cycle of operation. If the voltage applied to the input is of opposite polarity to that displayed by the instrument before sampling, the button will require pushing twice in order to obtain the correct reading. In this case the first reading obtained will be 0000.

5. **Input Terminals:** Three screw terminals, each drilled to accept a 4mm plug. The HI and LO terminals are fully isolated with guarded input. The third terminal is a CHASSIS connection.

6. **Link:** For normal measurements the link is connected between terminals LO and CHASSIS.



Fig. 2.4. Controls and Connectors.

Calibration

The following calibration procedure should be performed before taking a measurement which requires a high degree of accuracy. A 10 minute warm-up period should preferably be allowed before starting the calibration procedure.

1. Set the AUTO/MANUAL selector to AUTO.

2. Set RANGE switch to the CAL position.
3. Using a screwdriver adjust the CAL control for a display reading of +1.018.
4. Adjust the CAL control so that the units digit just changes to "9" i. e. the reading alternates between displays of +1.018 and +1.019. This corresponds to a reading of +1.0185.

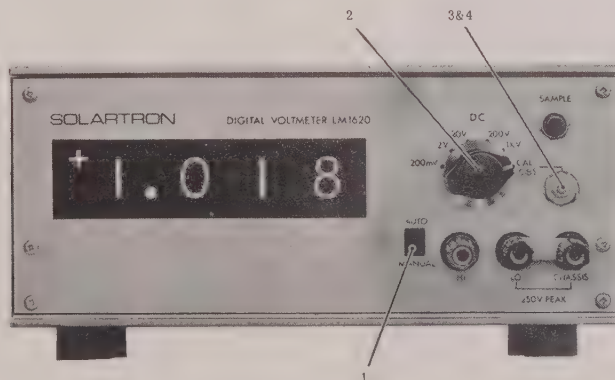


Fig. 2.5. Calibration.

SECTION 2

OPERATION

Installation

1. The instrument is wired ready for connection to a 184 - 265 volts mains supply. If 92 - 132 volt working is required the procedure described below should be followed:-

- Remove 4 screws from two plastic retainers on the instrument rear panel. Slide the top cover backwards and place aside.
- Alter the linking to the new format as shown in fig. 2, 3. Link location is shown in fig. 2, 2.

c) Replace the top cover by reversing the above procedure.

2. Check presence, continuity, and rating of the mains fuse. The value should be 150mA SLO, BLO for 184 - 265 volt operation and 300mA SLO, BLO for 92 - 132 volt operation.

3. Wire the mains lead to an appropriate mains plug, connecting:- red to LINE (L); black to NEUTRAL (N); green to EARTH (E).

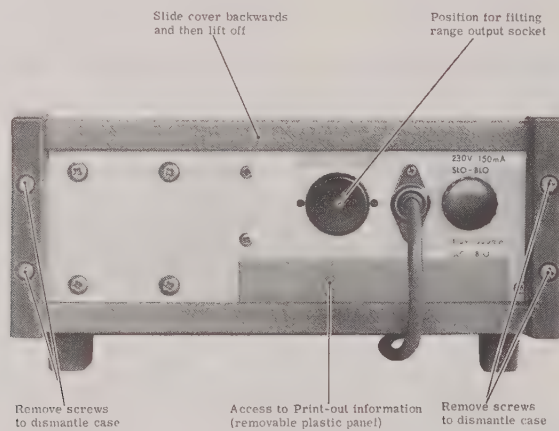


Fig. 2.1. Case Removal.

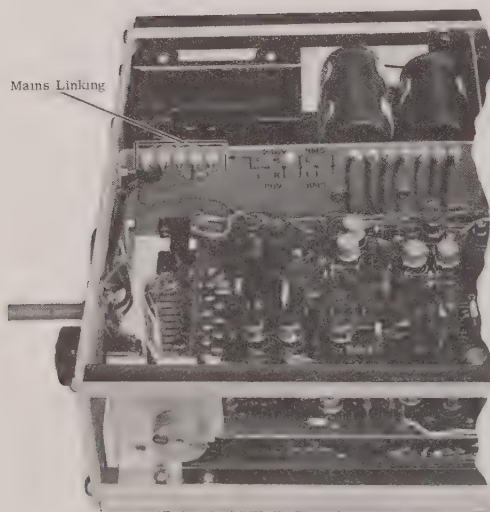
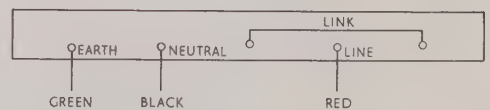
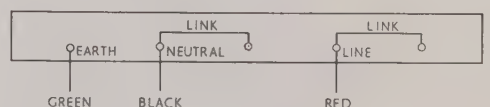


Fig. 2.2. Mains Link Location.



184-265 VOLTS WORKING



92-132 VOLTS WORKING

Fig. 2.3. Mains Linking.

COMPONENT LOCATION DIAGRAMS

LM1620 Underside Views	1
Main Frame Components and Preset Controls	2
Identification of Reed Relays and Test Points	3
Counter Board Assembly	4 - 5
Amplifier Board Assembly	6 - 7
Attenuator and Filter Board Assembly	8
Power Supply Board Assembly	8

COMPONENT PARTS LIST

Printed Circuit Board No. 1	1 - 4
Printed Circuit Board No. 2	4 - 6
Printed Circuit Board No. 3	6
Printed Circuit Board No. 4	6
Main Assembly	6

CIRCUIT DIAGRAMS

Sheets 1 and 2 - rear of Manual

ADDENDUM 1

Range Output Modification - rear of Manual

ADDENDUM 2

Series and Common Mode Interference - rear of Manual

ADDENDUM 3

Rack-mounting Procedure - rear of Manual

SECTION 1

GENERAL

Introduction

The LM1620 is a four window Digital Voltmeter employing a charge transfer digitising technique. The operational range of 0 - 1000 volts is covered in 5 ranges with a maximum sensitivity of 100 μ V, and an accuracy of $\pm 0.1\%$ of reading $\pm 0.05\%$ of full scale. Binary Coded Decimal information, polarity information and print command are obtained by attaching a PCB edge connector to the counter board. Range information is also available, and can be obtained at the rear panel by the addition of a B9A valve base with its associated wiring.

Specification

Ranges:

No	Range	Input Resistance	Sensitivity
1	0 - 199.9mV	>1000M Ω	100 μ V
2	0 - 1.999V		1mV
3	0 - 19.99V		10mV
4	0 - 199.9V	10M Ω	100mV
5	0 - 1000V	$\pm 1\%$	1V

Manual range selection with automatic positioning of decimal point.

Input Current: 10^{-10} Amps all ranges.

Polarity Indication: Polarity of input voltage is sensed and displayed automatically as a + or - sign.

Accuracy: $\pm 0.1\%$ of reading ± 1 digit. All ranges. Quoted accuracy is met after a 10 minute warm up time.

Calibration: Internal saturated standard cell provides calibration check to full accuracy over temperature range 15°C - 40°C.

Zero Stability: No zero adjustment is necessary over the operating temperature range of the instrument.

Temperature Coefficients: Internal standard cell $< 0.0045\%$ per °C. All ranges $< 0.02\%$ per °C. The instrument may be re-set to full accuracy at a given temperature (15°C - 40°C) using internal standard cell.

Operating Temperature Range: 0 to +50°C.

Long Term Stability: Internal Standard Cell

$< 0.05\%$ per year. All ranges $< \pm 0.1\%$ per year after calibration of basic range against internal standard cell (front panel preset control).

NOTE: Attenuated ranges may be reset to full accuracy using external standards.

Overload Protection: The instrument will withstand continuous overloads up to 350 volts on ranges 1 and 2 and up to 1000 volts on other ranges without damage.

Input Isolation: The two-terminal fully isolated and guarded input may be floated up to ± 250 volts DC or peak AC with respect to chassis (earth). Isolation impedance signal Lo to chassis 200M Ω in parallel with < 1000 pF. Input Lo may be linked to front panel chassis terminal. Input Hi and Lo terminals are completely isolated from printer output.

Operating Modes: Auto - 1, 1 - 2, 3 readings per second.

Sample - "single shot" by

(a) front panel push button.

or (b) remotely by contact closure or 6 volt negative going pulse of rise time $< 50\mu$ secs.

NOTE: If successive readings are of opposite polarity the instrument requires two samples to indicate correct polarity and magnitude of input.

Series Mode Rejection: A multi-section filter (permanently connected) provides > 40 dB attenuation of series mode interference at 45 Hz increasing at 12dB/octave at higher frequencies. The rejection is

defined as $20 \log_{10} \frac{\text{peak to peak input volts}}{\text{peak to peak error volts}}$

Filter Settling Time: < 1 second to full accuracy for zero to full scale step input.

Common Mode Rejection: Attenuation of Common mode signals with 1K Ω unbalance in either input lead.

Ranges 1 and 2 80 dB at DC and 50 Hz

Ranges 3 and 4 40 dB at DC and 50 Hz

Range 5 20 dB at DC and 50 Hz

Note: AC common mode defined as for series mode rejection.

Maximum common mode signal $\pm 250\text{V}$ DC or peak AC with respect to chassis (earth).

Power Input: 115/230 volts AC $\pm 15\%$, 44Hz to 440Hz, 25VA.

Dimensions: Housed in bench case: $8\frac{1}{2}"$ (21.6 cm) wide; $4\frac{1}{4}"$ (11cm) high; 16" (41 cm) deep.
For rack mounting: (See addendum 3) $8\frac{1}{2}"$ (21.6cm) wide; $3\frac{1}{2}"$ (8.9cm) high; 15" (38cm) deep (from front panel face).
Weight: 11 lbs (5kg)

Accessories: Supplied with instrument

- 1 - Input Lead.
- 2 - Alligator Clips.
- 2 - Test Prod Connectors.
- 1 - Input Terminal Link.

Optional Extra

Multi-way print out connector (Type EX1866).

Print out: Binary coded decimal (1248 code) plus polarity and print command outputs available from a multi-way connector at the rear of the instrument.
Logic Levels: -

	ON	OFF
	("1" State)	("0" State)
BCD and Polarity	- 5v to - 12v	0V to -1V
Maximum current	$\pm 1\text{mA}$ in either state.	
Print Command:	Change of voltage level from 0V to -6v from $1\text{K}\Omega$ source.	

Print out Information:

Pin No	Function
1	$\overline{4}_1$ *
2	4_1
3	$\overline{8}_1$ *
4	8_1
5	Internal Connection
6	Polarity -ve
7	Polarity +ve
8	External Trip
9	Print Command
10	Display Blanking
11	100kHz clock pulses
12	Reset line
13	No connection
14	Internal Connection
15	-12V rail (max. load 10ma nom.)
16	Common rail
17	+12V rail (max. load 5ma nom.)
18	+70V rail
19	+250V rail (max. load 5ma nom.)
20	Internal Connection
21	1_4

Print Out Information (cont)

Pin No	Function
A	$\overline{1}_1$ *
B	1_1
C	$\overline{2}_1$ *
D	2_1
E	$\overline{1}_2$ *
F	1_2
H	$\overline{2}_2$ *
J	2_2
K	$\overline{4}_2$ *
L	4_2
M	$\overline{8}_2$ *
N	8_2
P	No connection
R	$\overline{1}_3$ *
S	1_3
T	$\overline{2}_3$ *
U	2_3
V	$\overline{4}_3$ *
W	4_3
X	$\overline{8}_3$ *
Y	8_3

NOTE: There is a $1\text{K}\Omega$ resistor in series with all binary outputs except those marked with an asterisk (*).

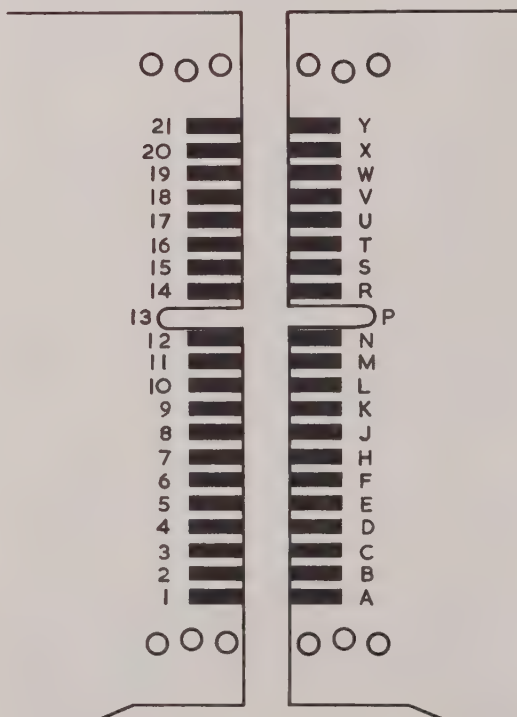
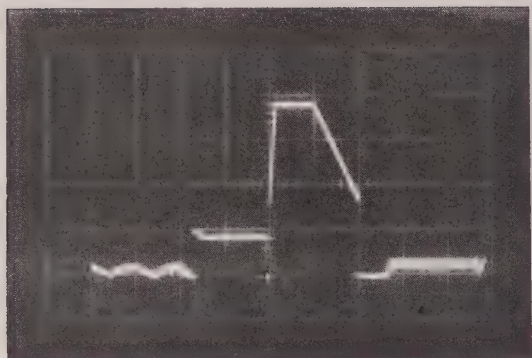
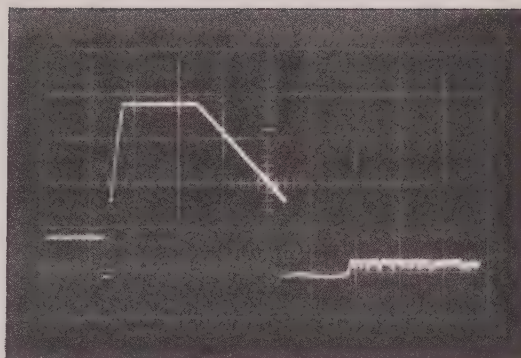


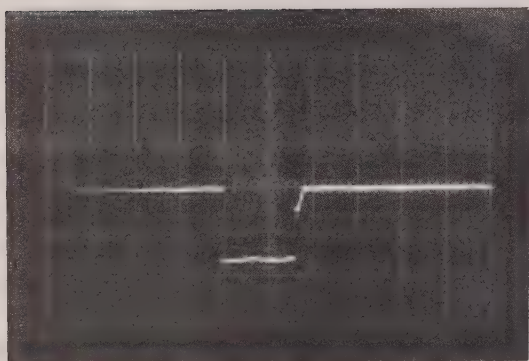
Fig. 1. 1. P. C. B. 1 Edge Connector Comb



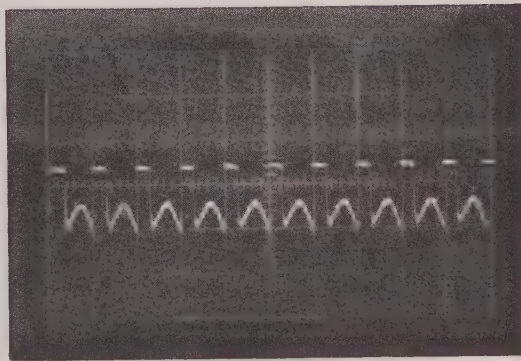
Amplifier Output Waveform
Deflection factor: 10V/cm.
Sweep time/cm.: 10mS.



Amplifier Output Waveform
Deflection factor: 10V/cm.
Sweep time/cm.: 5mS.



L.F. Multivibrator Output
Deflection factor: 10V/cm.
Sweep time/cm.: 10mS.



100KHz Clock Output
Deflection factor: 5V/cm.
Sweep time/cm.: 10 μ S.

The above photographs were taken with a standard oscilloscope camera fitted to a Solartron CD1220 oscilloscope incorporating a CX1256 wide-band plug-in amplifier and a CX1575 X10 compensated probe. LM1620 mode switch at AUTO; range switch at CAL.

Fig 5. 5 Typical Waveforms.

Calibration of Attenuated Ranges: With terminals LO and CHASSIS linked apply inputs from the voltage standard to terminals HI and LO and adjust the appropriate preset pots (located within the attenuator screened box) as detailed.

RANGE	INPUT	ADJUSTMENT	READING
20V	18V	RV1	18.00
200V	180V	CHECK RANGE	180.0
1kV	1000V	RV2	1000

Floating Input Zero Check: With terminals HI and LO linked but not connected to CHASSIS the instrument should display 0000 ± 1 on the 200mV range. Remove link from HI and LO and replace between LO and CHASSIS

Input Impedance Check: Apply inputs from the voltage standard to HI and LO via the 20M Ω resistor in series with signal HI. Readings within the limits stated correspond to an input impedance > 2000M Ω

RANGE	INPUT	READING
200MV	150mV	146.5 - 152.0
2V	1.5V	> 1.485

Input Current Check: With LO and CHASSIS terminals linked and the range selector at 200mV, connect the 20M Ω resistor between HI and LO. Apply a temporary short across HI and LO and allow the instrument to settle at zero. Remove the short and check that the reading builds up to a steady value of less than 002.0 (2mV), corresponding to < 10⁻¹⁰A. Remove the 20M Ω resistor.

Linearity Check: Select the 2V range and apply 1.9V from the voltage standard. Reduce the input level in 100mV steps down to 100mV, then in 10mV steps down to 10mV and finally in 1mV steps down to 0V.

Check that the readings obtained are accurate to within one bit throughout.

Series Mode Rejection Check: Apply a signal of 5V rms at 45Hz from the LF Oscillator to inputs HI and LO with the range selector at 2V and the mode switch at MANUAL. Measure the signal amplitude with the oscilloscope across C4 (the 0.47 μ F capacitor mounted on standoffs at the rear of the attenuator screened box). This signal should be < 50mV r. m. s. (141 mV p. p.).

Note: The earthy lead of the oscilloscope must be connected to the inner standoff

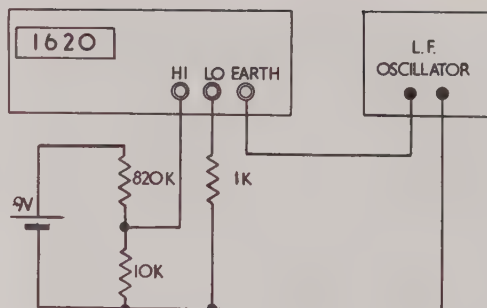


Fig. 5.3 AC Common Mode Test

Common Mode Rejection Check:

A. C. Common Mode: Remove the link between terminals LO and CHASSIS and select the 200mV range. Connect the circuit as shown in fig. 5.3 to HI and LO with the oscillator output set at zero. Increase the output to 3V r. m. s. and check that the reading varies by not more than 1mV.

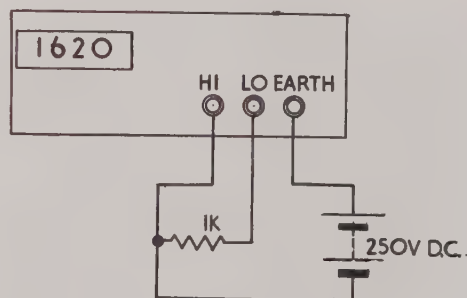
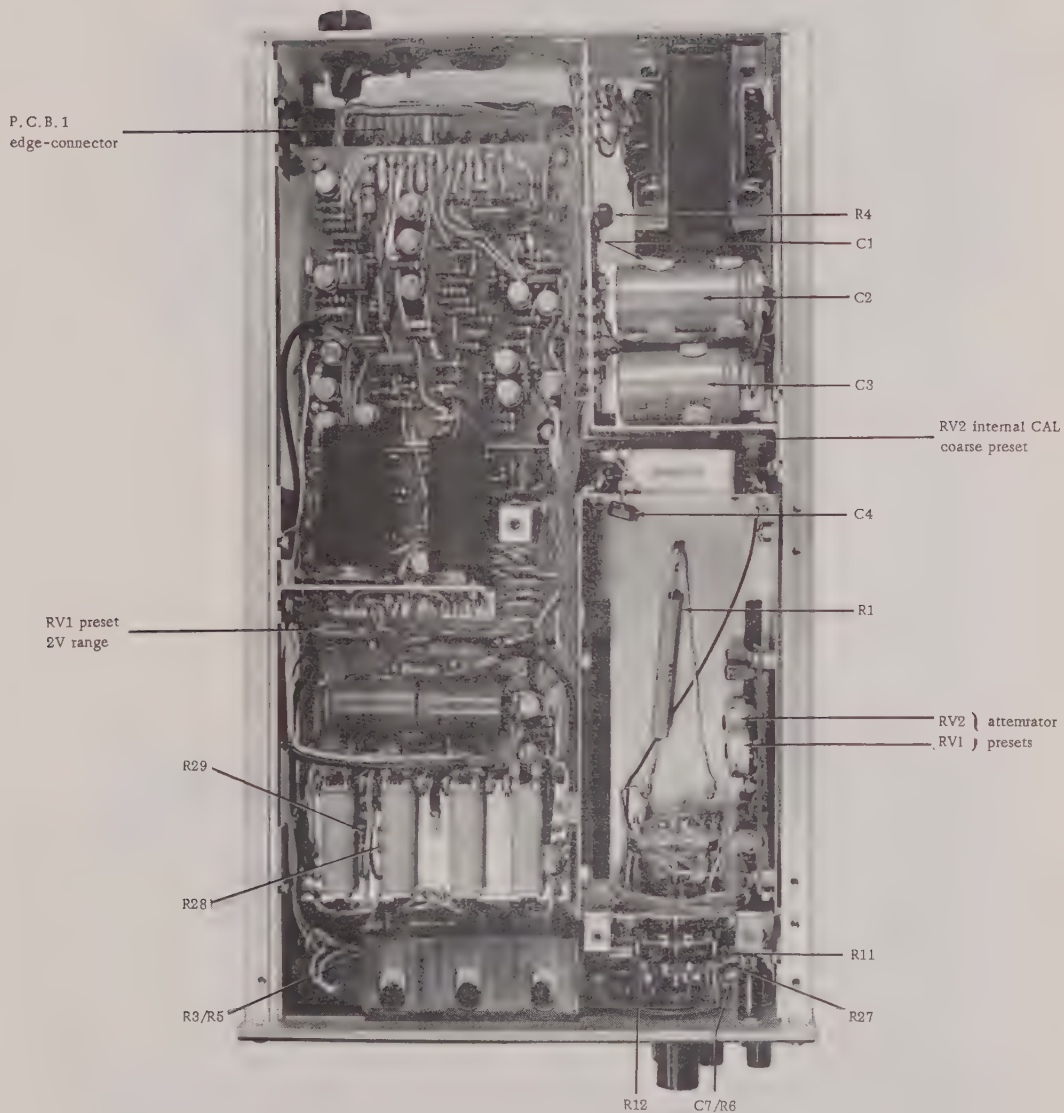
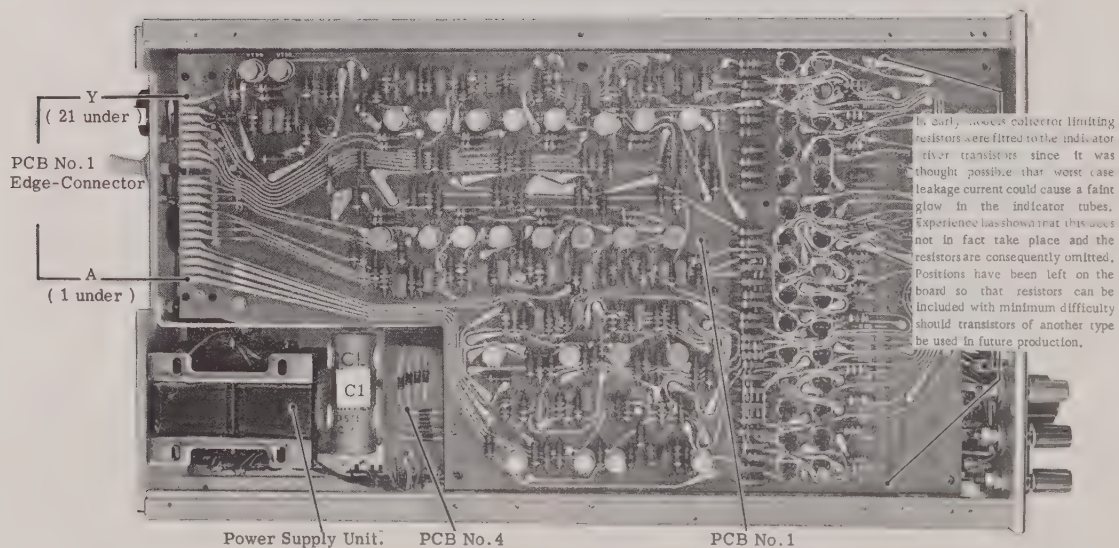
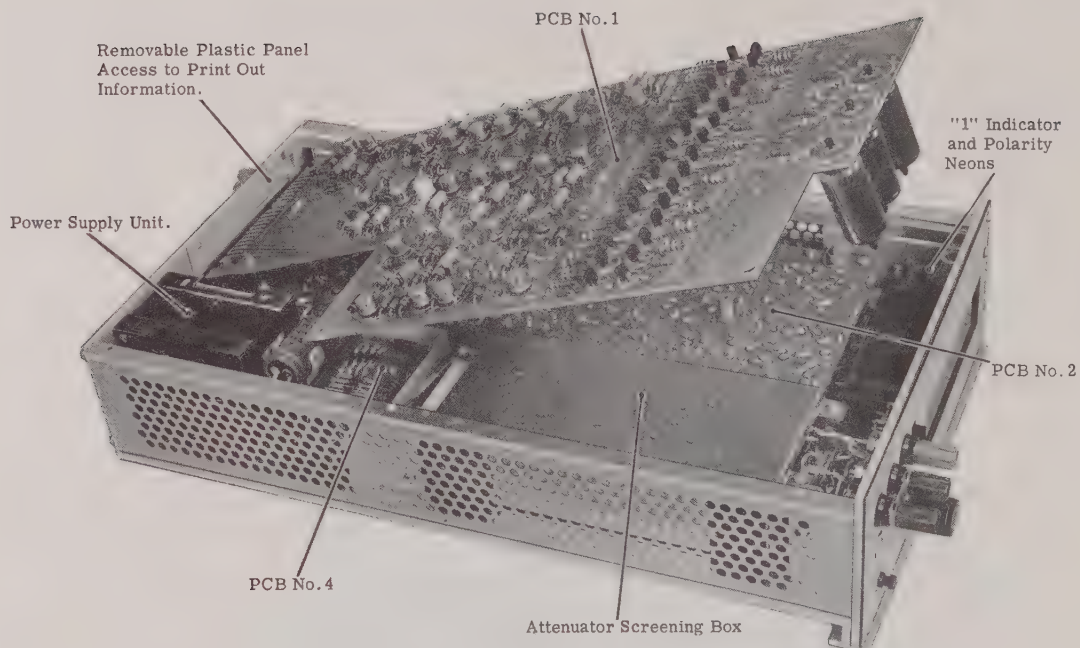


Fig. 5.4 DC Common Mode Test

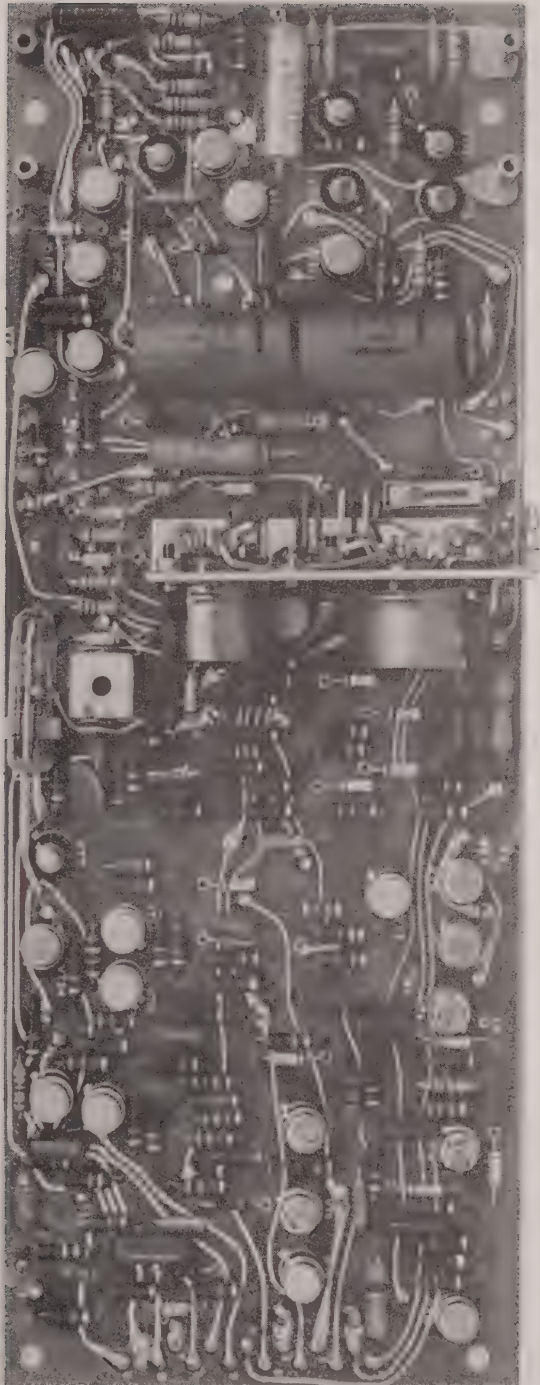
DC Common Mode: Connect the Circuit shown in fig. 5.4 to HI and LO and note the reading. Reverse the polarity of the DC supply and again note the reading. The larger of the two readings should be < 25mV.



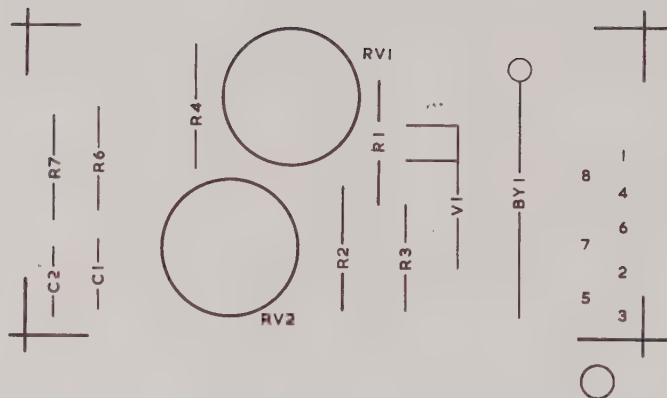
Main Frame Components and Preset Controls.



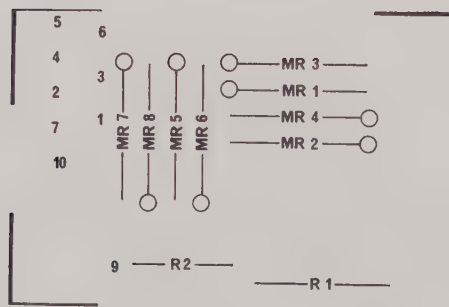
LM1620 Underside Views.



Amplifier Board Assembly Component Layout PCB No. 2,



Attenuator and Filter Board Assembly. Component Location PCB No. 3.



Power Supply Board Assembly Component Location PCB No. 4.

COMPONENT PARTS LIST

COMPONENT PARTS LIST						R9	X	22K	$\frac{1}{2}$ W	10%	172342200						
Abbreviations						R10	Z	100	$\frac{1}{2}$ W	5%	193521000						
Circuit Reference						R11	X	6800	$\frac{1}{2}$ W	10%	172336800						
						R12	X	1000	$\frac{1}{2}$ W	10%	172331000						
						R	Fixed Resistor (Ω)				R13	X	12K	$\frac{1}{2}$ W	10%	172341200	
						RV	Variable Resistor (Ω)				R14	Z	1000	$\frac{1}{2}$ W	5%	193531000	
						C	Capacitor (μ F)				R15	Not fitted					
						MR	Diode				R16	Not fitted					
						VT	Transistor				R17	X	10K	$\frac{1}{2}$ W	10%	172341000	
						V	Valve				R18	X	39K	$\frac{1}{2}$ W	10%	172343900	
						S	Switch				R19	X	1200	$\frac{1}{2}$ W	10%	172331200	
						RL	Relay				R20	X	12K	$\frac{1}{2}$ W	10%	172341200	
						FS	Fuse				R21	X	10K	$\frac{1}{2}$ W	10%	172341000	
						BY	Battery				R22	X	12K	$\frac{1}{2}$ W	10%	172341200	
						T	Transformer				R23	X	56K	$\frac{1}{2}$ W	10%	172345600	
						XL	Crystal				R24	X	39K	$\frac{1}{2}$ W	10%	172343900	
						ILP	Lamp				R25	X	1000	$\frac{1}{2}$ W	10%	172331000	
						RL	Relay				R26	Not fitted					
Component						R27	X	10K	$\frac{1}{2}$ W	10%	172341000						
						R28	X	1200	$\frac{1}{2}$ W	10%	172331200						
						V	Resistor Metal Film Insulated				R29	Not fitted					
						W	Resistor Carbon, Insulated, Tolerance < 5%				R30	X	10K	$\frac{1}{2}$ W	10%	172341000	
						X	Resistor Composition, Insulated Tolerance > 5%				R31	X	39K	$\frac{1}{2}$ W	10%	172343900	
						Y	Resistor Wire Wound, Vitreous				R32	X	12K	$\frac{1}{2}$ W	10%	172341200	
						Z	Resistor Oxide Film, Insulated Tolerance < 5%				R33	X	10K	$\frac{1}{2}$ W	10%	172341000	
						WW	Wire Wound				R34	X	1200	$\frac{1}{2}$ W	10%	172331200	
						Po	Polyester				R35	X	12K	$\frac{1}{2}$ W	10%	172341200	
						Ce. T	Ceramic Tube Ins.				R36	X	10K	$\frac{1}{2}$ W	10%	172341000	
						Ce. D	Ceramic Disc Ins.				R37	Not fitted					
						El	Electrolytic				R38	X	56K	$\frac{1}{2}$ W	10%	172345600	
						Pe	Polystyrene				R39	X	15K	$\frac{1}{2}$ W	10%	172341500	
						Pe T	Polystyrene Tube Ins.				R40	X	39K	$\frac{1}{2}$ W	10%	172343900	
						COMPONENT PARTS LIST for Printed Circuit Board No. 1						R41	X	1000	$\frac{1}{2}$ W	10%	712331000
												R42	Not fitted				
R43	X	10K	$\frac{1}{2}$ W	10%	172341000												
R44	X	1200	$\frac{1}{2}$ W	10%	172331200												
R45	X	39K	$\frac{1}{2}$ W	10%	172343900												
R46	X	10K	$\frac{1}{2}$ W	10%	172341000												
R47	X	12K	$\frac{1}{2}$ W	10%	172341200												
R48	X	12K	$\frac{1}{2}$ W	10%	172341200												
R49	Not fitted																
R50	X	10K	$\frac{1}{2}$ W	10%	172341000												
Cct Ref						R51	X	1500	$\frac{1}{2}$ W	10%	172331500						
						R52	Not fitted										
						R2	Z	47K	$\frac{1}{2}$ W	5%	193544700	R53	X	10K	$\frac{1}{2}$ W	10%	172341000
						R3	Z	1000	$\frac{1}{2}$ W	5%	193531000	R54	X	39K	$\frac{1}{2}$ W	10%	172343900
						R4	X	6800	$\frac{1}{2}$ W	10%	172336800	R55	X	56K	$\frac{1}{2}$ W	10%	172345600
						R5	Z	100	$\frac{1}{2}$ W	5%	193521000	R56	X	12K	$\frac{1}{2}$ W	10%	172341200
						R6	X	33K	$\frac{1}{2}$ W	10%	172343300	R57	X	39K	$\frac{1}{2}$ W	10%	172343900
						R7	X	12K	$\frac{1}{2}$ W	10%	172341200	R58	Not fitted				
						R8	X	12K	$\frac{1}{2}$ W	10%	172341200	R59	X	1000	$\frac{1}{2}$ W	10%	172331000

R60	X	10K	$\frac{1}{2}$ W	10%	172341000	R114	X	10K	$\frac{1}{2}$ W	10%	172341000
R61	X	1500	$\frac{1}{2}$ W	10%	172331500	R115	X	1500	$\frac{1}{2}$ W	10%	172331500
R62	X	10K	$\frac{1}{2}$ W	10%	172341000	R116	Not fitted				
R63	X	10K	$\frac{1}{2}$ W	10%	172341000	R117	X	10K	$\frac{1}{2}$ W	10%	172341000
R64	Not fitted					R118	X	39K	$\frac{1}{2}$ W	10%	172343900
R65	Z	47K	$\frac{1}{2}$ W	5%	193544700	R119	X	56K	$\frac{1}{2}$ W	10%	172345600
R66	Z	1000	$\frac{1}{2}$ W	5%	193531000	R120	X	12K	$\frac{1}{2}$ W	10%	172341200
R67	X	6800	$\frac{1}{2}$ W	10%	172336800	R121	X	39K	$\frac{1}{2}$ W	10%	172343900
R68	Z	100	$\frac{1}{2}$ W	5%	193521000	R122	X	10K	$\frac{1}{2}$ W	10%	172341000
R69	X	33K	$\frac{1}{2}$ W	10%	172343300	R123	X	1000	$\frac{1}{2}$ W	10%	172331000
R70	X	12K	$\frac{1}{2}$ W	10%	172341200	R124	Not fitted				
R71	X	12K	$\frac{1}{2}$ W	10%	172341200	R125	X	1500	$\frac{1}{2}$ W	10%	172331500
R72	X	22K	$\frac{1}{2}$ W	10%	172342200	R126	X	10K	$\frac{1}{2}$ W	10%	172341000
R73	X	6800	$\frac{1}{2}$ W	10%	172336800	R127	X	10K	$\frac{1}{2}$ W	10%	172341000
R74	X	1000	$\frac{1}{2}$ W	10%	172331000	R128	Not fitted				
R75	X	12K	$\frac{1}{2}$ W	10%	172341200	R129	Z	100	$\frac{1}{2}$ W	5%	193521000
R76	Z	100	$\frac{1}{2}$ W	5%	193521000	R130	Z	1000	$\frac{1}{2}$ W	5%	193531000
R77	Z	1000	$\frac{1}{2}$ W	5%	193531000	R131	X	6800	$\frac{1}{2}$ W	10%	172336800
R78	Not fitted					R132	Z	47K	$\frac{1}{2}$ W	5%	193544700
R79	X	10K	$\frac{1}{2}$ W	10%	172341000	R133	X	33K	$\frac{1}{2}$ W	10%	172343300
R80	Not fitted					R134	X	12K	$\frac{1}{2}$ W	10%	172341200
R81	X	10K	$\frac{1}{2}$ W	10%	172341000	R135	X	12K	$\frac{1}{2}$ W	10%	172341200
R82	X	39K	$\frac{1}{2}$ W	10%	172343900	R136	X	22K	$\frac{1}{2}$ W	10%	172342200
R83	X	12K	$\frac{1}{2}$ W	10%	172341200	R137	X	1000	$\frac{1}{2}$ W	10%	172331000
R84	X	1200	$\frac{1}{2}$ W	10%	172331200	R138	X	6800	$\frac{1}{2}$ W	10%	172336800
R85	X	10K	$\frac{1}{2}$ W	10%	172341000	R139	X	12K	$\frac{1}{2}$ W	10%	172341200
R86	X	12K	$\frac{1}{2}$ W	10%	172341200	R140	Z	100	$\frac{1}{2}$ W	5%	193521000
R87	X	56K	$\frac{1}{2}$ W	10%	172345600	R141	Z	1000	$\frac{1}{2}$ W	5%	193531000
R88	Not fitted					R142	Not fitted				
R89	X	1000	$\frac{1}{2}$ W	10%	172331000	R143	X	10K	$\frac{1}{2}$ W	10%	172341000
R90	X	39K	$\frac{1}{2}$ W	10%	172343900	R144	Not fitted				
R91	X	10K	$\frac{1}{2}$ W	10%	172341000	R145	X	39K	$\frac{1}{2}$ W	10%	172343900
R92	X	1200	$\frac{1}{2}$ W	10%	172331200	R146	X	10K	$\frac{1}{2}$ W	10%	172341000
R93	Not fitted					R147	X	1200	$\frac{1}{2}$ W	10%	172331200
R94	X	10K	$\frac{1}{2}$ W	10%	172341000	R148	X	12K	$\frac{1}{2}$ W	10%	172341200
R95	X	39K	$\frac{1}{2}$ W	10%	172343900	R149	X	10K	$\frac{1}{2}$ W	10%	172341000
R96	X	12K	$\frac{1}{2}$ W	10%	172341200	R150	X	56K	$\frac{1}{2}$ W	10%	172345600
R97	X	10K	$\frac{1}{2}$ W	10%	172341000	R151	X	12K	$\frac{1}{2}$ W	10%	172341200
R98	X	12K	$\frac{1}{2}$ W	10%	172341200	R152	Not fitted				
R99	X	1200	$\frac{1}{2}$ W	10%	172331200	R153	X	39K	$\frac{1}{2}$ W	10%	172343900
R100	X	10K	$\frac{1}{2}$ W	10%	172341000	R154	X	10K	$\frac{1}{2}$ W	10%	172341000
R101	Not fitted					R155	X	1000	$\frac{1}{2}$ W	10%	172331000
R102	X	56K	$\frac{1}{2}$ W	10%	172345600	R156	X	1200	$\frac{1}{2}$ W	10%	172331200
R103	X	15K	$\frac{1}{2}$ W	10%	172341500	R157	Not fitted				
R104	X	39K	$\frac{1}{2}$ W	10%	172343900	R158	X	10K	$\frac{1}{2}$ W	10%	172341000
R105	X	1000	$\frac{1}{2}$ W	10%	172331000	R159	X	39K	$\frac{1}{2}$ W	10%	172343900
R106	Not fitted					R160	X	12K	$\frac{1}{2}$ W	10%	172341200
R107	X	10K	$\frac{1}{2}$ W	10%	172341000	R161	X	10K	$\frac{1}{2}$ W	10%	172341000
R108	X	1200	$\frac{1}{2}$ W	10%	172331200	R162	X	12K	$\frac{1}{2}$ W	10%	172341200
R109	X	39K	$\frac{1}{2}$ W	10%	172343900	R163	X	1200	$\frac{1}{2}$ W	10%	172331200
R110	X	12K	$\frac{1}{2}$ W	10%	172341200	R164	X	10K	$\frac{1}{2}$ W	10%	172341000
R111	X	10K	$\frac{1}{2}$ W	10%	172341000	R165	X	56K	$\frac{1}{2}$ W	10%	172345600
R112	X	12K	$\frac{1}{2}$ W	10%	172341200	R166	Not fitted				
R113	Not fitted					R167	X	15K	$\frac{1}{2}$ W	10%	172341500

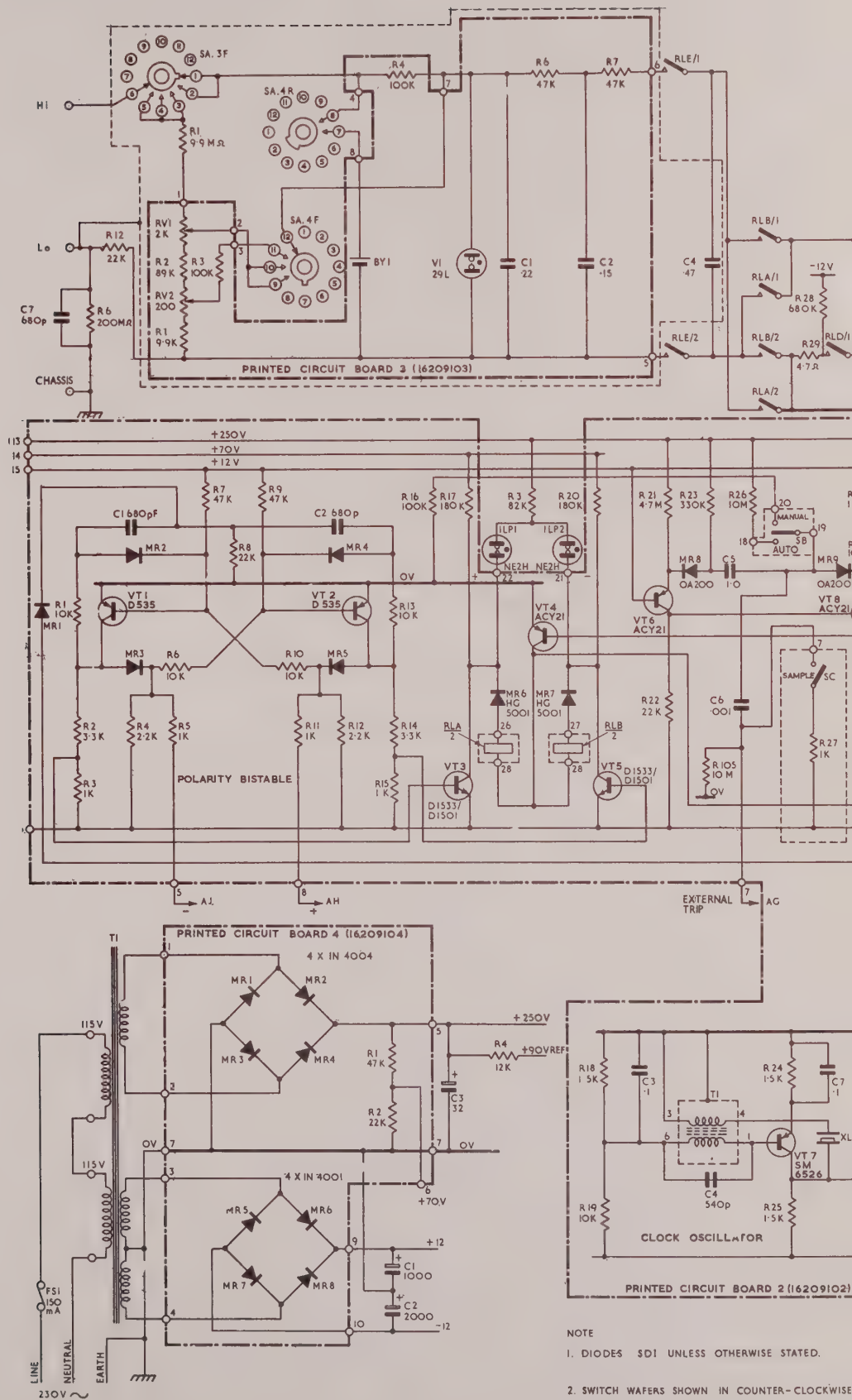
R168	X	39K	$\frac{1}{2}$ W	10%	172343900	C22	Ce,D	0, 1	3V	-0	
R169	X	10K	$\frac{1}{2}$ W	10%	172341000					+100%	208450076
R170	Not fitted					C23	Ce,D	0, 1	3V	-0	
R171	X	39K	$\frac{1}{2}$ W	10%	172343900					+100%	208450076
R172	X	1200	$\frac{1}{2}$ W	10%	172331200	C24					
R173	X	12K	$\frac{1}{2}$ W	10%	172341200	to	Ce,T	470p	500V	10%	208400084
R174	X	10K	$\frac{1}{2}$ W	10%	172341000	C32					
R175	X	12K	$\frac{1}{2}$ W	10%	172341200	MR1					
R176	Not fitted					to	SD1				300520070
R177	X	10K	$\frac{1}{2}$ W	10%	172341000	MR39					
R178	Not fitted					MR40	1N4004		Motorola		300522070
R179	X	1500	$\frac{1}{2}$ W	10%	172331500						
R180	X	10K	$\frac{1}{2}$ W	10%	172341000	VT1	D1533/D1501		Texas Inst.		300553340
R181	X	39K	$\frac{1}{2}$ W	10%	172343900	VT2	D535		Texas Inst.		300551620
R182	X	56K	$\frac{1}{2}$ W	10%	172345600	VT3	D535		Texas Inst.		300551620
R183	X	39K	$\frac{1}{2}$ W	10%	172343900	VT4	D1533/D1501		Texas Inst.		300553340
R184	X	10K	$\frac{1}{2}$ W	10%	172341000	VT5	D1533/D1501		Texas Inst.		300553340
R185	X	1000	$\frac{1}{2}$ W	10%	172331000	VT6	D535		Texas Inst.		300551620
R186	X	12K	$\frac{1}{2}$ W	10%	172341200	VT7	D1533/D1501		Texas Inst.		300553340
R187	Not fitted					VT8	D535		Texas Inst.		300551620
R188	X	1500	$\frac{1}{2}$ W	10%	172331500	VT9	D1533/D1501		Texas Inst.		300553340
R189	X	10K	$\frac{1}{2}$ W	10%	172341000	VT10	D535		Texas Inst.		300551620
R190	Z	56K	$\frac{1}{2}$ W	5%	193545600	VT11	D1533/D1501		Texas Inst.		300553340
R191	Z	56K	$\frac{1}{2}$ W	5%	193545600	VT12	D1533/D1501		Texas Inst.		300553340
R192	Z	56K	$\frac{1}{2}$ W	5%	193545600	VT13	D535		Texas Inst.		300551620
R193	X	10K	$\frac{1}{2}$ W	10%	172341000	VT14	D1533/D1501		Texas Inst.		300553340
R194	X	1500	$\frac{1}{2}$ W	10%	172331500	VT15	D535		Texas Inst.		300551620
R195	X	10K	$\frac{1}{2}$ W	10%	172341000	VT16	D1533/D1501		Texas Inst.		300553340
R196	X	56K	$\frac{1}{2}$ W	10%	172345600	VT17	D1533/D1501		Texas Inst.		300553340
R197	X	39K	$\frac{1}{2}$ W	10%	172343900	VT18	D535		Texas Inst.		300551620
R198	X	10K	$\frac{1}{2}$ W	10%	172341000	VT19	D1533/D1501		Texas Inst.		300553340
R199	X	1500	$\frac{1}{2}$ W	10%	172331500	VT20	D535		Texas Inst.		300551620
R200	X	10K	$\frac{1}{2}$ W	10%	172341000	VT21	D535		Texas Inst.		300551620
R201	X	15K	$\frac{1}{2}$ W	10%	172341500	VT22	D1533/D1501		Texas Inst.		300553340
R202	X	39K	$\frac{1}{2}$ W	10%	172343900	VT23	D1533/D1501		Texas Inst.		300553340
R203	X	1000	$\frac{1}{2}$ W	10%	172331000	VT24	D535		Texas Inst.		300551620
R204	Z	150K	$\frac{1}{2}$ W	5%	193551500	VT25	D1533/D1501		Texas Inst.		300553340
R205	X	1000	$\frac{1}{2}$ W	10%	172331000	VT26	D535		Texas Inst.		300551620
						VT27	D1533/D1501		Texas Inst.		300553340
C1	Ce,D	0, 1	3V	-0		VT28	D535		Texas Inst.		300551620
				+100%	208450076	VT29	D1533/D1501		Texas Inst.		300553340
C2	Pe,T	470p	30V	20%	208100130	VT30	D1533/D1501		Texas Inst.		300553340
C3	Pe,T	470p	30V	20%	208100130	VT31	D535		Texas Inst.		300551620
C4	Ce,D	0, 1	3V	-0		VT32	D1533/D1501		Texas Inst.		300553340
				+100%	208450076	VT33	D535		Texas Inst.		300551620
C5						VT34	D1533/D1501		Texas Inst.		300553340
to	Ce,T	470p	500V	10%	208400084	VT35	D1533/D1501		Texas Inst.		300553340
C11						VT36	D535		Texas Inst.		300551620
C12	Ce,D	0, 1	3V	-0		VT37	D1533/1501		Texas Inst.		300553340
				+100%	208450076	VT38	D535		Texas Inst.		300551620
C13	Ce,D	0, 1	3V	-0		VT39	D535		Texas Inst.		300551620
				+100%	208450076	VT40	D1533/D1501		Texas Inst.		300553340
C14						VT41	D1533/D1501		Texas Inst.		300553340
to	Ce,T	470p	500V	10%	208400084	VT42	D535		Texas Inst.		300551620
C21						VT43	D1533/D1501		Texas Inst.		300553340

VT44	D535	Texas Inst.	300551620	R29	X	1. 5M	$\frac{1}{2}$ W	10%	172361500		
VT45	D1533/D1501	Texas Inst.	300553340	R30	X	10K	$\frac{1}{2}$ W	10%	172341000		
VT46	D535	Texas Inst.	300551620	R31	X	680	$\frac{1}{2}$ W	10%	172326800		
VT47	D1533/D1501	Texas Inst.	300553340	R32	X	10K	$\frac{1}{2}$ W	10%	172341000		
VT48	D1533/D1501	Texas Inst.	300553340	R33	X	1. 5M	$\frac{1}{2}$ W	10%	172361500		
VT49	D535	Texas Inst.	300551620	R34	X	10K	$\frac{1}{2}$ W	10%	172341000		
VT50	D1533/D1501	Texas Inst.	300553340	R35	X	6800	$\frac{1}{2}$ W	10%	172336800		
VT51	D535	Texas Inst.	300551620	R36	Z	62K	$\frac{1}{2}$ W	1%	195446200		
VT52	D1533/D1501	Texas Inst.	300553340	R37	Z	120K	$\frac{1}{2}$ W	1%	195451200		
VT53	D1533/D1501	Texas Inst.	300553340	R38	X	1500	$\frac{1}{2}$ W	10%	172331500		
VT54	D535	Texas Inst.	300551620	R39	X	6800	$\frac{1}{2}$ W	10%	172336800		
VT55	D535	Texas Inst.	300551620	R40	X	10K	$\frac{1}{2}$ W	10%	172341000		
VT56	D535	Texas Inst.	300551620	R41	Z	27K	$\frac{1}{2}$ W	1%	195442700		
VT57	D1533/D1501	Texas Inst.	300553340	R42	Z	39K	$\frac{1}{2}$ W	1%	195443900		
				R43	Z	1800	$\frac{1}{2}$ W	1%	195431800		
				R44	X	56K	$\frac{1}{2}$ W	10%	172345600		
V1	ZM1080	Mullard	300011330	R45	Z	1000	$\frac{1}{2}$ W	1%	195431000		
V2	ZM1080	Mullard	300011330	R46	X	33K	$\frac{1}{2}$ W	10%	172343300		
V3	ZM1080	Mullard	300011330	R47	Z	6800	$\frac{1}{2}$ W	5%	193536800		
				R48	X	2200	$\frac{1}{2}$ W	10%	172332200		
				R49	X	39K	$\frac{1}{2}$ W	10%	172343900		
	COMPONENT PARTS LIST			R50	Z	1000	$\frac{1}{2}$ W	1%	195431000		
	for			R51	X	15	$\frac{1}{2}$ W	10%	172311500		
	Printed Circuit Board No. 2			R52	X	10K	$\frac{1}{2}$ W	10%	172341000		
				R53	X	10K	$\frac{1}{2}$ W	10%	172341000		
Cct.			Solartron	R54	X	330	$\frac{1}{2}$ W	10%	172323300		
Ref.	General Description		Part No.	R55	X	1000	$\frac{1}{2}$ W	10%	172331000		
				R56	X	10K	$\frac{1}{2}$ W	10%	172341000		
R1	X	10K	$\frac{1}{2}$ W	10%	172341000	R57	X	10K	$\frac{1}{2}$ W	10%	172341000
R2	X	3300	$\frac{1}{2}$ W	10%	172333300	R58	Z	3900	$\frac{1}{2}$ W	1%	195433900
R3	X	1000	$\frac{1}{2}$ W	10%	172331000	R59	X	22K	$\frac{1}{2}$ W	10%	172342200
R4	X	2200	$\frac{1}{2}$ W	10%	172332200	R60	Z	3300	$\frac{1}{2}$ W	1%	195433300
R5	X	1000	$\frac{1}{2}$ W	10%	172331000	R61	Z	620	$\frac{1}{2}$ W	1%	195426200
R6	X	10K	$\frac{1}{2}$ W	10%	172341000	R62	Z	3900	$\frac{1}{2}$ W	1%	195433900
R7	X	47K	$\frac{1}{2}$ W	10%	172344700	R63	X	4700	$\frac{1}{2}$ W	10%	172334700
R8	X	22K	$\frac{1}{2}$ W	10%	172342200	R64	X	1000	$\frac{1}{2}$ W	10%	172331000
R9	X	47K	$\frac{1}{2}$ W	10%	172344700	R65	X	680	$\frac{1}{2}$ W	10%	172326800
R10	X	10K	$\frac{1}{2}$ W	10%	172341000	R66	Z	3300	$\frac{1}{2}$ W	1%	195433300
R11	X	1000	$\frac{1}{2}$ W	10%	172331000	R67	Z	1800	$\frac{1}{2}$ W	1%	195431800
R12	X	2200	$\frac{1}{2}$ W	10%	172332200	R68	X	33K	$\frac{1}{2}$ W	10%	172343300
R13	X	10K	$\frac{1}{2}$ W	10%	172341000	R69	X	10K	$\frac{1}{2}$ W	10%	172341000
R14	X	3300	$\frac{1}{2}$ W	10%	172333300	R70	X	4700	$\frac{1}{2}$ W	10%	172334700
R15	X	1000	$\frac{1}{2}$ W	10%	172331000	R71	X	100	$\frac{1}{2}$ W	10%	172321000
R16	X	100K	$\frac{1}{2}$ W	10%	172351000	R72	X	15K	$\frac{1}{2}$ W	10%	172341500
R17	X	180K	$\frac{1}{2}$ W	10%	172351800	R73	X	47	$\frac{1}{2}$ W	10%	172314700
R18	X	1500	$\frac{1}{2}$ W	10%	172331500	R74	Z	3300	$\frac{1}{2}$ W	1%	195433300
R19	X	10K	$\frac{1}{2}$ W	10%	172341000	R75	X	1500	$\frac{1}{2}$ W	10%	172331500
R20	X	180K	$\frac{1}{2}$ W	10%	172351800	R76	Z	3300	$\frac{1}{2}$ W	1%	195433300
R21	X	4. 7M	$\frac{1}{2}$ W	10%	172364700	R77	Z	1800	$\frac{1}{2}$ W	1%	195431800
R22	Z	22K	$\frac{1}{2}$ W	5%	193542200	R78	X	68K	$\frac{1}{2}$ W	10%	172346800
R23	Z	330K	$\frac{1}{2}$ W	5%	193553300	R79	X	10K	$\frac{1}{2}$ W	10%	172341000
R24	X	1500	$\frac{1}{2}$ W	10%	172331500	R80	X	10K	$\frac{1}{2}$ W	10%	172341000
R25	X	1500	$\frac{1}{2}$ W	10%	172331500	R81	X	10K	$\frac{1}{2}$ W	10%	172341000
R26	X	10M	$\frac{1}{2}$ W	10%	172371000	R82	X	10K	$\frac{1}{2}$ W	10%	172341000
R28	Z	68K	1W	5%	193446800	R83	W	4. 7	1/8W	5%	170204700

COMPONENT PARTS LIST
for
Printed Circuit Board No. 2

R84	Z	100K	$\frac{1}{2}$ W	5%	193451000	MR1	SD1		300520070
R85	X	1000	$\frac{1}{2}$ W	10%	172331000	MR2	SD1		300520070
R86	X	1000	$\frac{1}{2}$ W	10%	172331000	MR3	SD1		300520070
R87	X	10K	$\frac{1}{2}$ W	10%	172341000	MR4	SD1		300520070
R88	X	4700	$\frac{1}{2}$ W	10%	172334700	MR5	SD1		300520070
R89	X	3300	$\frac{1}{2}$ W	10%	172333300	MR6	HG5001	Hughes	300523650
R90	V	9.1M	1W	0.5%	B16200085	MR7	HG5001	Hughes	300523650
R91	X	12K	$\frac{1}{2}$ W	10%	172341200	MR8	OA200	Mullard	300520720
R92	V	900K	$\frac{1}{4}$ W	0.25%	160400369	MR9	OA200	Mullard	300520720
R93	Z	2700	$\frac{1}{2}$ W	5%	193532700	MR10	SZD6, 8		300522540
R94	Z	220K	$\frac{1}{2}$ W	5%	193552200	MR11	OA200	Mullard	300520720
R95	Z	33K	$\frac{1}{2}$ W	5%	193543300	MR12	SD1		300520070
R96	Z	150K	$\frac{1}{2}$ W	5%	193551500	MR13	SD1		300520070
R97	Z	3900	$\frac{1}{2}$ W	1%	195433900	MR14	SD1		300520070
R98	X	1200	$\frac{1}{2}$ W	10%	172331200	MR15	HG5001	Hughes	300523650
R99	Z	1800	$\frac{1}{2}$ W	1%	195431800	MR16	SD1		300520070
R100	X	100	$\frac{1}{2}$ W	10%	172321000	MR17	SD1		300520070
R101	X	1200	$\frac{1}{2}$ W	10%	172331200	MR18	SZD6, 8		300522540
R102	Z	6800	1W	1%	197536800	MR19	SD1		300520070
R103	X	100K	$\frac{1}{2}$ W	10%	172351000	MR20	SZD6, 8		300522540
R104	X	10K	$\frac{1}{2}$ W	10%	172341000	MR21	1N3595	Fairchild	300523590
R105	X	10M	$\frac{1}{2}$ W	10%	172371000	MR22	1N3595	Fairchild	300523590
RV1	W	20K	$\frac{1}{2}$ W	10%	110152200	MR23	1N3595	Fairchild	300523590
						MR24	SD1		300520070
						MR25	OA202	Mullard	300521040
C1	Ce.T	680p	500V	10%	208400097	MR26	SD1		300520070
C2	Ce.T	680p	500V	10%	208400097	MR27	SD1		300520070
C3	Ce.D	0.1	3V	-0	208450076	MR28	SD1		300520070
C4	Pe.T	540p	125V	2.5%		MR29	SZD6, 8		300522540
				210125400					
C5	Po	1.0	60V	10%	225161000	VT1	D535	Texas Inst	300551620
C6	Ce.T	1000p	500V	20%	208400048	VT2	D535	Texas Inst	300551620
						VT3	D1533/		
C7	Ce.D	0.1	18V	-25	208450052		D1501	Texas Inst.	300553340
C8	Ce.T	220p	500V	10%		VT4	ACY21	Mullard	300550490
				208400046	VT5	D1533/			
C9	Ce.D	0.1	18V	-25	208450052		D1501	Texas Inst.	300553340
C10	Po	1.0	60V	20%		VT6	ACY21	Mullard	300550490
				225261000	VT7	SM6526	Motorola	300552590	
C11	Ce.T	680p	500V	10%	208400097	VT8	ACY21	Mullard	300550490
C12	Po	0.068	250V	20%	225846800	VT9	ACY21	Mullard	300550490
C13	Ce.T	1000p	500V	20%	208400048	VT10	D535	Texas Inst	300551620
C14	Po	0.01	400V	20%	226141000	VT11	SM6526	Motorola	300552590
C15	El	250	15V	-20	208600149	VT12	D1533/		
C16	Ce.T	2200p	500V	20%			D1501	Texas Inst.	300553340
				208400083	VT13	D1533/			
C17	Po	0.1	100V	10%	225451000		D1501	Texas Inst.	300553340
C18	Pe	0.47	63V	1%	208100127	VT14	ACY21	Mullard	300550490
C19	Pe	0.47	63V	1%	208100127	VT15	D535	Texas Inst	300551620
C20	Po	0.068	250V	5%	208200116	VT16	2N2484	Fairchild	300552860
C21	Ce.T	2200p	500V	20%	208400083	VT17	2N2484	Fairchild	300552860
C22	Po	.047	250V	5%	208200120	VT18	D1533/		
C23	Ce.T	2200p	500V	20%	208400083		D1501	Texas Inst.	300553340
C24	Po	0.1	250V	20%	225851000	VT19	SM6526	Motorola	300552590
C26	Po	.01	400V	20%	226141000	VT20	D535	Texas Inst	300551620

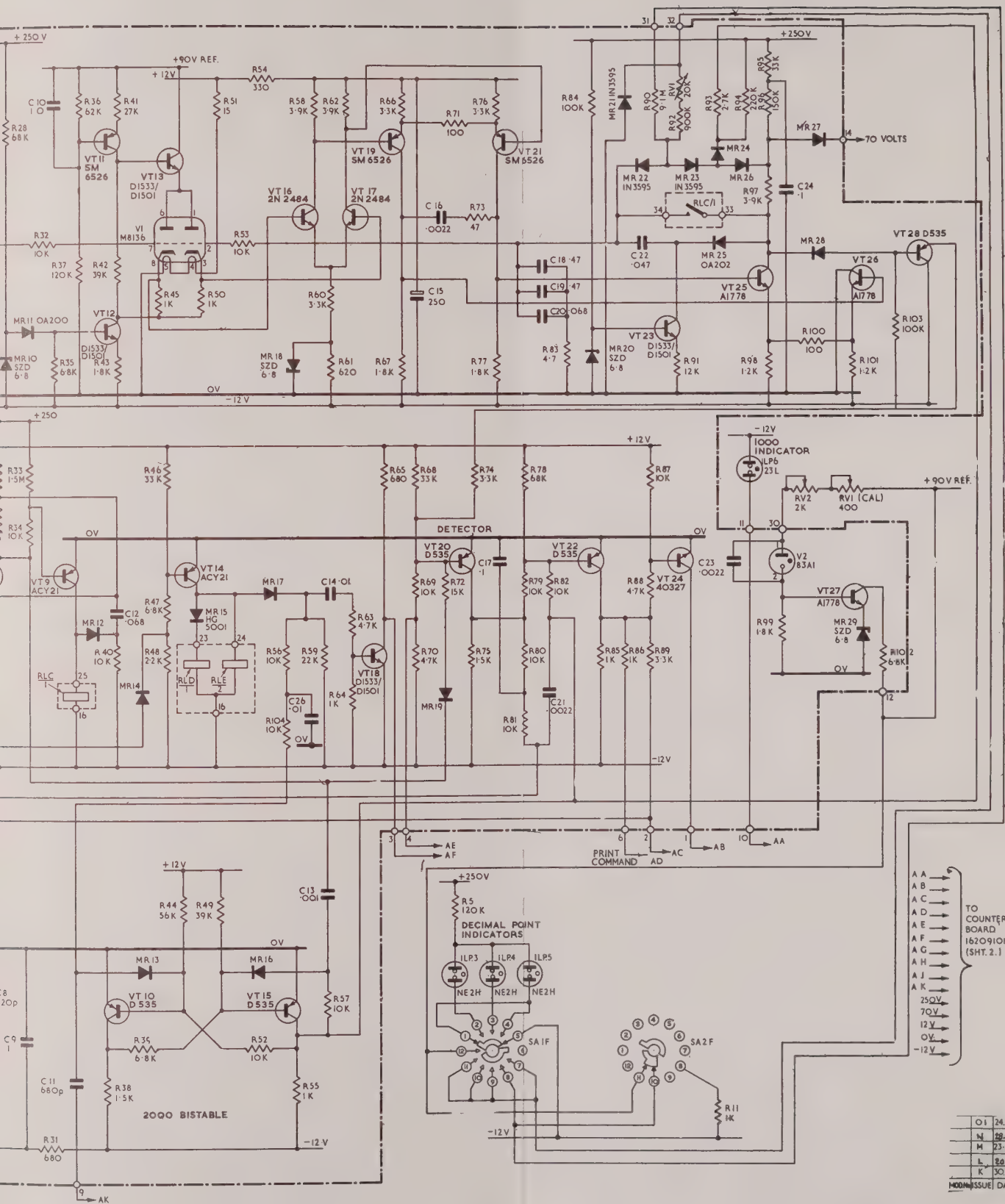
VT21	SM6526	Motorola	300552590	MR5	1N4001	Motorola	300522060				
VT22	D535	Texas Inst	300551620	MR6	1N4001	Motorola	300522060				
VT23	D1533/ D1501	Texas Inst.	300553340	MR7	1N4001	Motorola	300522060				
VT24	40327	R. C. A.	300552890	MR8	1N4001	Motorola	300522060				
VT25	A1778/1	Fairchild	300551430	COMPONENT PARTS LIST for Main Assembly							
VT26	A1778/1	Fairchild	300551430								
VT27	A1778/1	Fairchild	300551430								
VT28	D535	Texas Inst	300551620								
V1	M8136	Mullard	300033091	Cct. Ref.	General Description				Solartron Part No.		
V2	83A1	Mullard	300011110	R1	V	9.9M	2W	0.5%	B16200103		
XL1	4435	STC	A16200011	R3	X	82K	$\frac{1}{2}$ W	10%	172348200		
T1		Solartron	B16200012	R4	Y	12K	3W	1%	A16200113		
COMPONENT PARTS LIST for Printed Circuit Board No. 3				R5	X	120K	$\frac{1}{2}$ W	10%	172351200		
				R6	X	200M	$\frac{1}{2}$ W	20%	160100026		
				R11	X	1000	$\frac{1}{2}$ W	10%	172331000		
				R12	X	22K	$\frac{1}{2}$ W	10%	172342200		
				R27	X	1000	$\frac{1}{2}$ W	10%	172331000		
				R28	X	680K	$\frac{1}{2}$ W	10%	172356800		
				R29	X	4.7	$\frac{1}{2}$ W	$\pm .5\Omega$	160100122		
Cct. Ref.	General Description			Solartron Part No.	RV1	WW	400	$\frac{1}{4}$ W	10%	110075130	
R1	V	9900	$\frac{1}{4}$ W	0.25%	160400363	RV2	WW	2000	1W	5%	121932000
R2	V	89K	$\frac{1}{4}$ W	0.25%	160400364	C1	El	1000	15V	-20	208600177
R3	X	100K	$\frac{1}{2}$ W	10%	172351000	C2	El	2000	15V	-20	
R4	Z	100K	$\frac{1}{2}$ W	1%	197551000					+100%	
R6	Z	47K	$\frac{1}{2}$ W	5%	193544700	C3	El	32	350V	-20	208600178
R7	Z	47K	$\frac{1}{2}$ W	5%	193544700					+100%	
RV1	WW	2000	$\frac{1}{2}$ W	20%	110031250	C4	Po	0.47	100V	5%	208200130
RV2	WW	200	$\frac{1}{2}$ W	20%	110031420					C7	Pe
C1	Po	0.22	100V	5%	208200123	FS1	Fuse Link		150mA	Slow	360105040
C2	Po	0.15	100V	5%	208200132	T1	Mains Transformer			Blow	
V1	29L	Hivac	300720170	B16200001							
BY1		Standard Cell	B16200084	RLA	Relay & Coil Assy				AD16200093		
COMPONENT PARTS LIST for Printed Circuit Board No. 4				RLB	Relay & Coil Assy				AD16200093		
				RLC	Relay & Coil Assy				AD16200094		
				RLD	Relay & Coil Assy				AD16200094		
				RL E	Relay & Coil Assy				AD16200093		
				SA	Switch Wafer Front				B16200040		
Cct. Ref.	General Description			Solartron Part No.	SB	Switch Slider				375000450	
R1	Z	47K	$\frac{1}{2}$ W	1%	197544700	SC	Switch P. B.				377000130
						ILP1	NE2H	Lamp Neon	300720220		
						IL. 2	NE2H	Lamp Neon	300720220		
						ILP3	NE2H	Lamp Neon	300720220		
						ILP4	NE2H	Lamp Neon	300720220		
MR1	1N4004	Motorola	300522070	ILP5	NE2H	Lamp Neon	300720220				
MR2	1N4004	Motorola	300522070	ILP6	23L	Lamp Neon	300720240				
MR3	1N4004	Motorola	300522070	Note: Diode SD1 is a Solartron specification based on Mullard OA91 parameters.							
MR4	1N4004	Motorola	300522070								



NOTE

1. DIODES SD1 UNLESS OTHERWISE STATED.

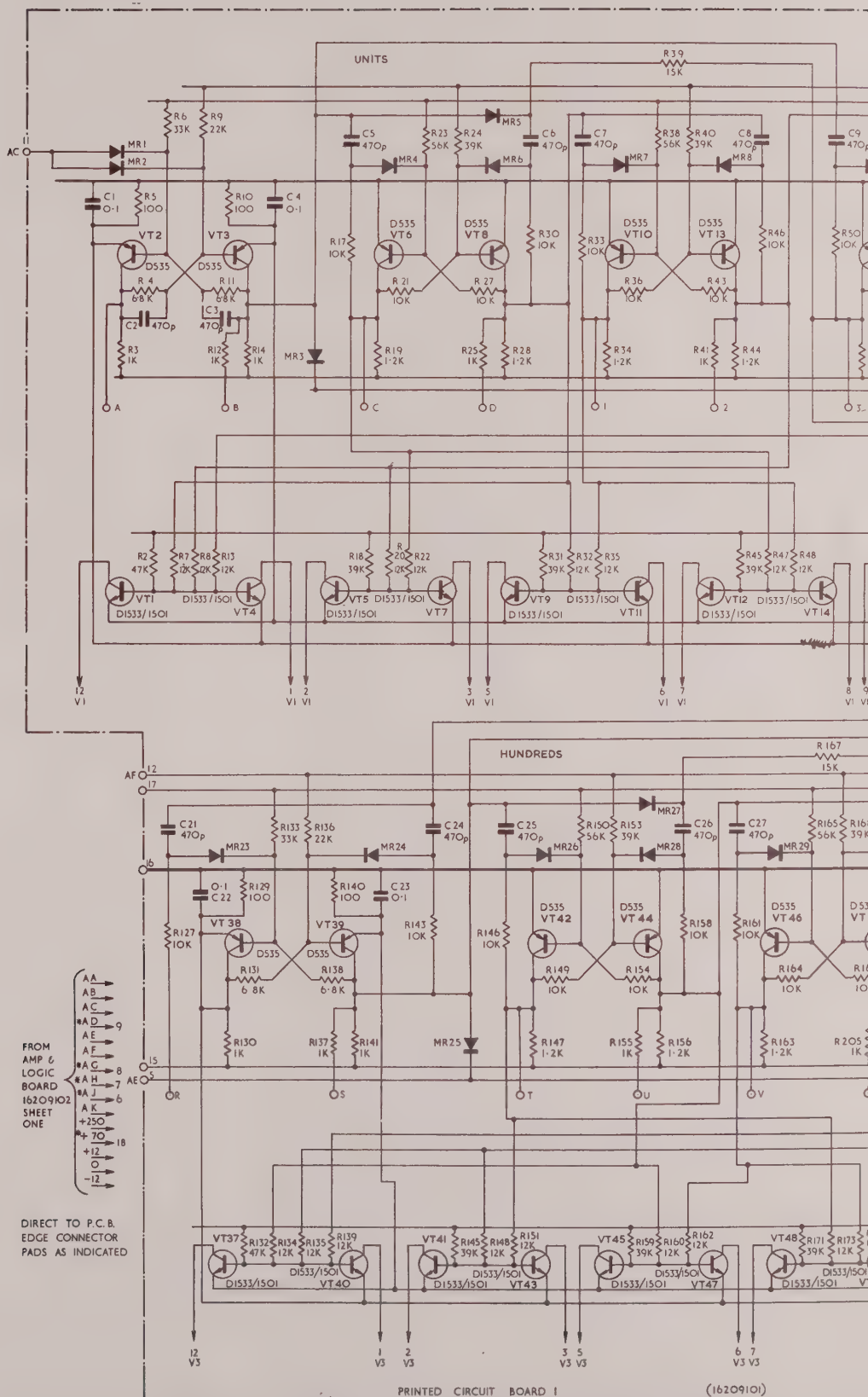
2. SWITCH WAFERS SHOWN IN COUNTER-CLOCKWISE

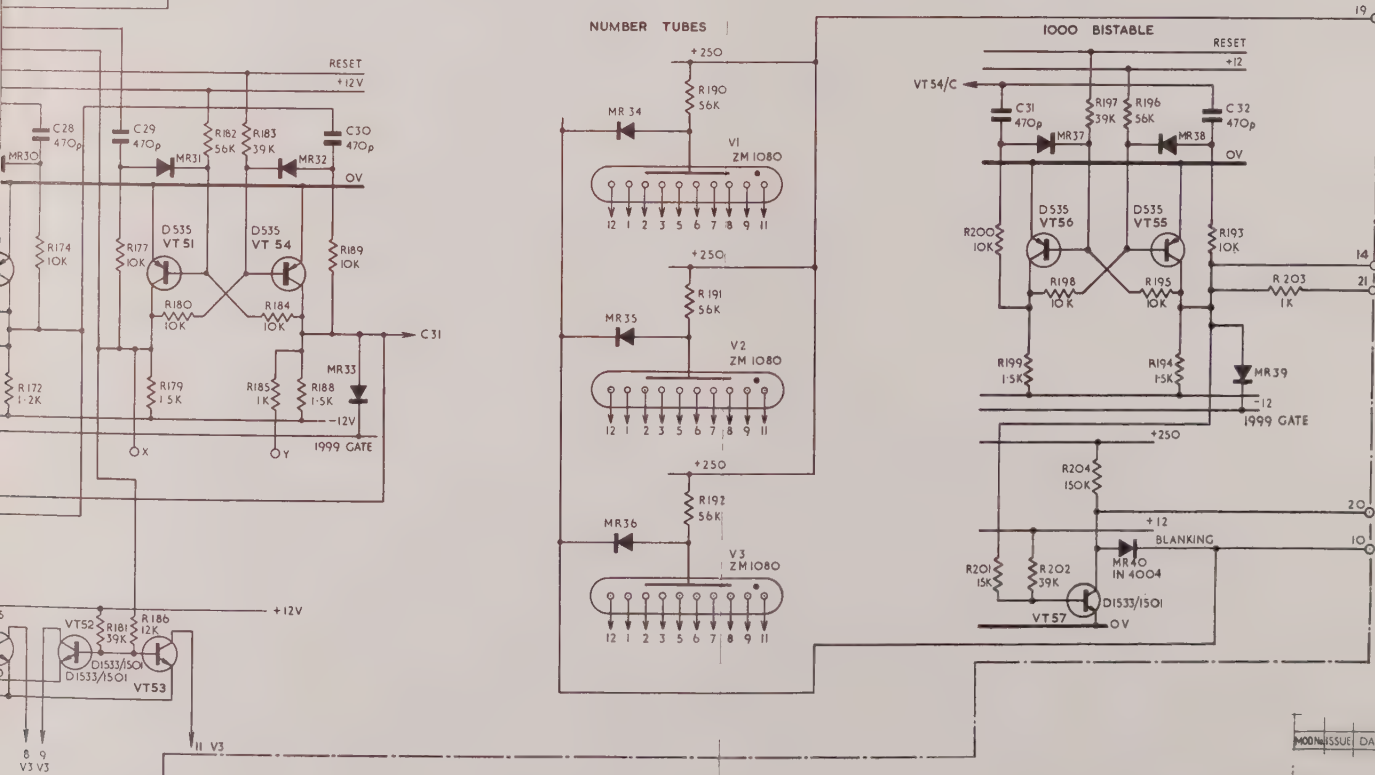
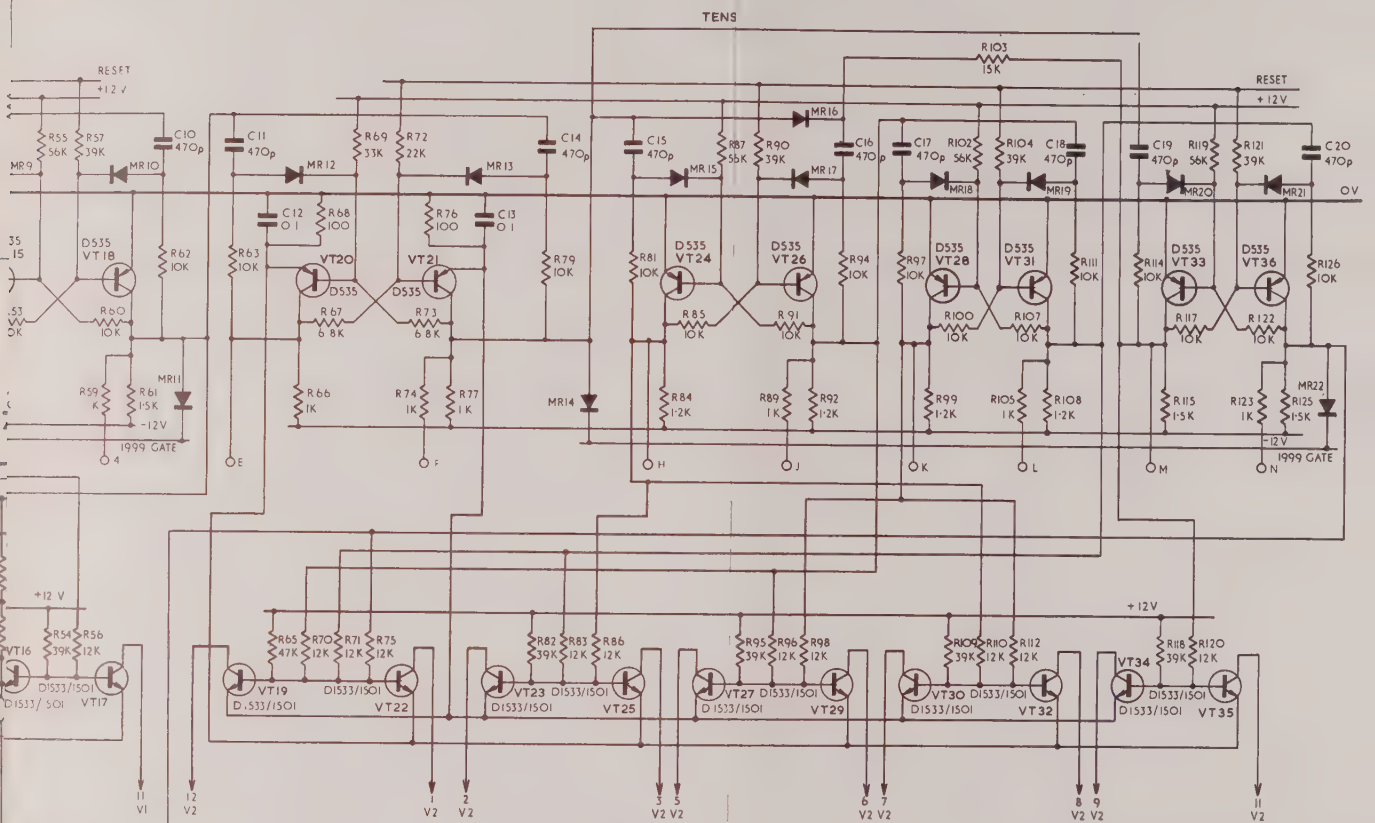


D 16207001 (SHT. 1 OF 2)

DIGITAL VOLTMETER LM 1620

SITION (200 MV RANGE)





ADDENDUM 1 RANGE OUTPUT MODIFICATION

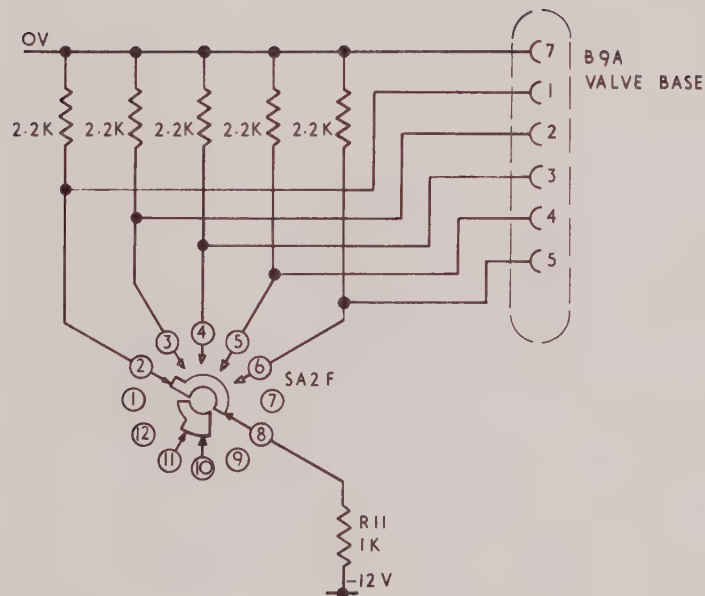


Diagram 1

This modification may be carried out if range output information is required to augment the print-out information provided. When completed the modification provides outputs of approximately -8 volts via 1000Ω [R11] on five lines via switchbank SA2F of the range selector.

Parts List

- 5 - resistor 2200Ω $\frac{1}{2}$ W 10%
- 1 - valve base B9A
- 2 - screw, cheesehead 6BA x 3/8"
- 2 - whole unit 6BA
- 2 - star washer 6BA
- 1 - solder tag 6BA
- 5 - wire, 7/0076 x 17" length [assorted colours]
18 S.W.G. tinned copper wire - as required
lacing cord, nylon - as required.

Assembly Instructions

The completed modification will consist of five resistors mounted on a B9A valve base fitted at the rear panel of the instrument. The five connecting wires run parallel to the existing cableform alongside the power supply sub-chassis and attenuator box to spare contacts 2 to 6 of switch wafer SA2F. Resistor R11 [1K] is already fitted and the fixing hole for the valve base is provided, blanked off with a removable bung.

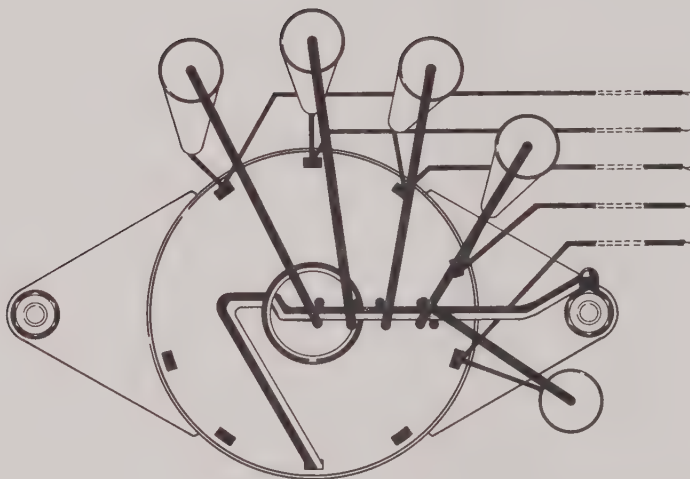


Diagram 2

1. Wire valve base as shown in diagram 2 and take note of the colour coding of the connecting wires to the pins of the valve base.
2. Remove the bung in the rear panel of the instrument and fit the valve base.
3. Arrange the connecting wires into a cableform and lace up. Route to the front of the instrument beside existing cableform.
4. Cut to length, strip and solder each connecting lead to the tags of switch wafer SA2F as per circuit diagram. [Component Location 2 shows the positioning of the contact tags of switch wafer SA2F].

This completes the modification.

Final Check .

Connect the instrument to the mains supply and measure the outputs with a voltmeter at pins 1 - 5 of the valve base.

An output of approximately -8V should appear at each pin with appropriate positioning of the range selector as listed.

Range	Output
200mV	Pin 1
2V	Pin 2
20V	Pin 3
200V	Pin 4
1kV	Pin 5

Affect on Instrument Calibration.

Provided that care has been taken not to disturb any preset controls during the modification work the calibration of the instrument should not be affected. It is good practice, however, to carry out the test procedure as described in Section 5 of the manual following any internal work carried out on the instrument.

Decode to BCD

If the output device available requires the range information to be presented in BCD form the following decode matrix may be of use. The output level will be reduced by the forward voltage drop from a maximum of two diodes. The actual value determined by the diode type employed.

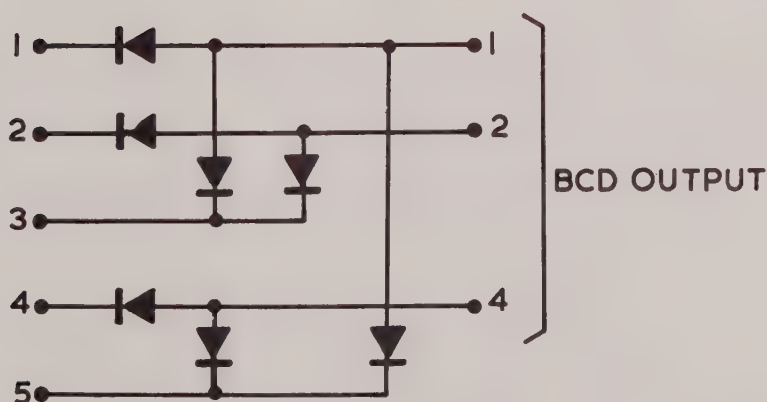


Diagram 3

ADDENDUM 2

SERIES AND COMMON MODE INTERFERENCE

General

The digital voltmeter is a very sensitive instrument capable of measuring with extreme precision. Consequently, interference signals induced into its input leads or originating in the source under measurement will give rise to spurious inputs capable of rendering a reading valueless when very small signals are applied to the instrument.

To overcome such difficulties special techniques are employed in both the design and operation of the voltmeter and their consideration is conveniently carried out by classifying interference in two forms - common mode and series mode.

Series Mode

This is generated in series with the signal source and is sometimes called 'Normal Mode'.

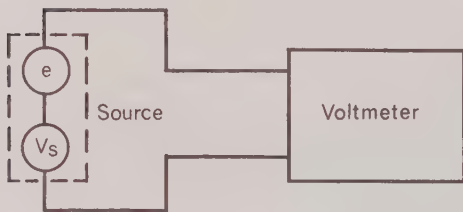


Diagram A



Diagram B

It may arise as part of the source, as shown in Diagram A, where the signal to be measured (e) and the interference (V_s) are superimposed upon one another, or as pick-up on the connecting leads, Diagram B.

If a D.C. source is being measured and the interference is also D.C. the unwanted signal must be cancelled by a backing off technique. This facility is not usually built in to digital voltmeters. It is rarely required. It is more usual that the interference be A.C., either generated from within the source or picked up on the leads.

The permanently connected filter of LM 1620 provides greater than 40dB rejection of series mode interference at 50Hz, increasing at 12dB per octave at high frequencies. Thus with a display of 1 volt, interference at 50Hz will have to be at least 100mV in order to produce flicker in the last (1mV) window. Similarly, at least 10 volts of interference at 400Hz are required for flicker to occur.

Common Mode

This, by definition, is interference common to both input leads of the voltmeter, all input circuitry moving with respect to earth. This interference will not in itself give rise to errors, since the voltmeter will measure the difference in potential between its input terminals. However, in most circumstances, the common mode interference will give rise to a series mode signal capable of introducing errors.

In the older type of instrument it was frequently the practice to take signal LO to chassis and thence to mains earth. If the signal source was also earthed, the circuit became that of Diagram C.

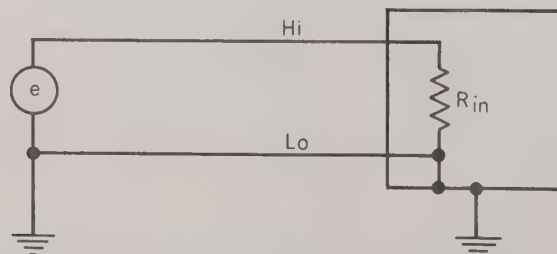


Diagram C.

It is now generally realised that the two 'earths' are not necessarily at the same potential, and in industrial instrumentation there may be a potential of several volts between them. This is developed across the impedance of the LO lead and a current of several amps may flow. Hence, the error will be equal to the potential difference between the two 'earths'.

It is thus very desirable to have fully floating input circuits so that the source may be tied to a potential which is not earth. Diagram D shows a floating input circuit employed to measure a source (e) which is at a common mode potential (V_C). The common mode current which flows in the LO lead is now limited to a very low value by the leakage resistance to chassis. With LM1620 V_C may be as much as 250V peak or D.C., while the leakage resistance R_L is 200M Ω .

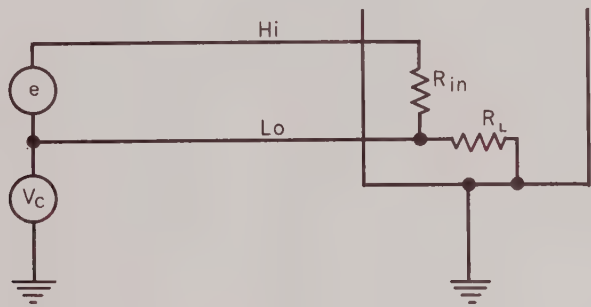


Diagram D.

The input circuit of the LM1620 is contained within a totally screened compartment isolated from earth as shown in diagram E. For floating measurements the link between terminals LO and CHASSIS should be removed.

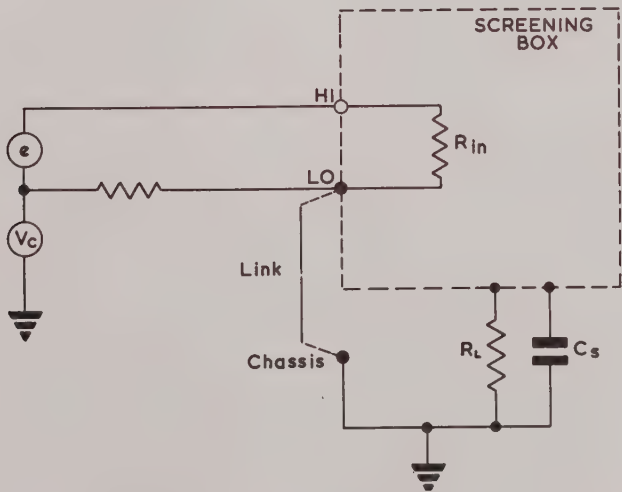


Diagram E.

Common Mode Performance

The performance is specified as a ratio and expressed in dB's. For both AC and DC common mode performance on the basic ranges (200mV and 2V) is better than 80dB. This means that, for an interference voltage V_C , the error will be 80dB down on V_C . Alternatively, a 10V peak or DC common mode signal will give an error reading of 1mV.

The shunting effect of the stray capacitance C_S on unbalanced A.C. common mode signals is compensated for by the permanently connected filter.

The LM1620 common mode performance is independent of input attenuation but is qualified by the two values of amplifier sensitivity. The three values of input attenuation thus appear as common mode multipliers as shown in table 1.

RANGE	ATTENUATION	BASIC SENSITIVITY	COMMON MODE REJECTION	1 bit =	V_C for 1 bit error
200mV	0	200mV	80dB (10, 000: 1)	100 μ V	1V
2V	0	2V	80dB	1mV	10V
20V	X100	200mV	40dB (100 : 1)	10mV	1V
200V	X100	2V	40dB	100mV	10V
1KV	X1000	2V	20dB (10 : 1)	1V	10V

Table 1.

The common mode specification is quoted with a resistive unbalance of 1000 Ω in either input lead. Unbalance up to, typically, 10k Ω will be tolerated with little degradation of performance.

ADDENDUM 3

RACK MOUNTING

Introduction

The LM1620 conforms to international standard (ISEP) constructional formats allowing for simple installation in 19" racking.

Preparatory

- 1) Remove top and bottom covers.
- 2) Remove two "T" section cover retaining strips from front-panel.
- 3) Remove range selector knob, input terminal link and six 6BA Phillips-headed screws from front-panel.
- 4) The melamine facia may now be removed to reveal the two fixing holes at the bottom of the front-panel.
- 5) Mark-through and drill two corresponding holes in the melamine facia. (Ready drilled facia-panels can be supplied on request).

Installation

Diagram 1 shows all the relevant dimensions and tolerances of the complete instrument chassis with panels removed.

Where a particularly rigid installation is required ISEP standard rack-mounting kits are commercially available.

For permanent installations, where the rack is unlikely to be moved, it should be sufficient in view of the light weight of the instrument for it to be mounted with two fixing screws between two parallel ISEP bars.

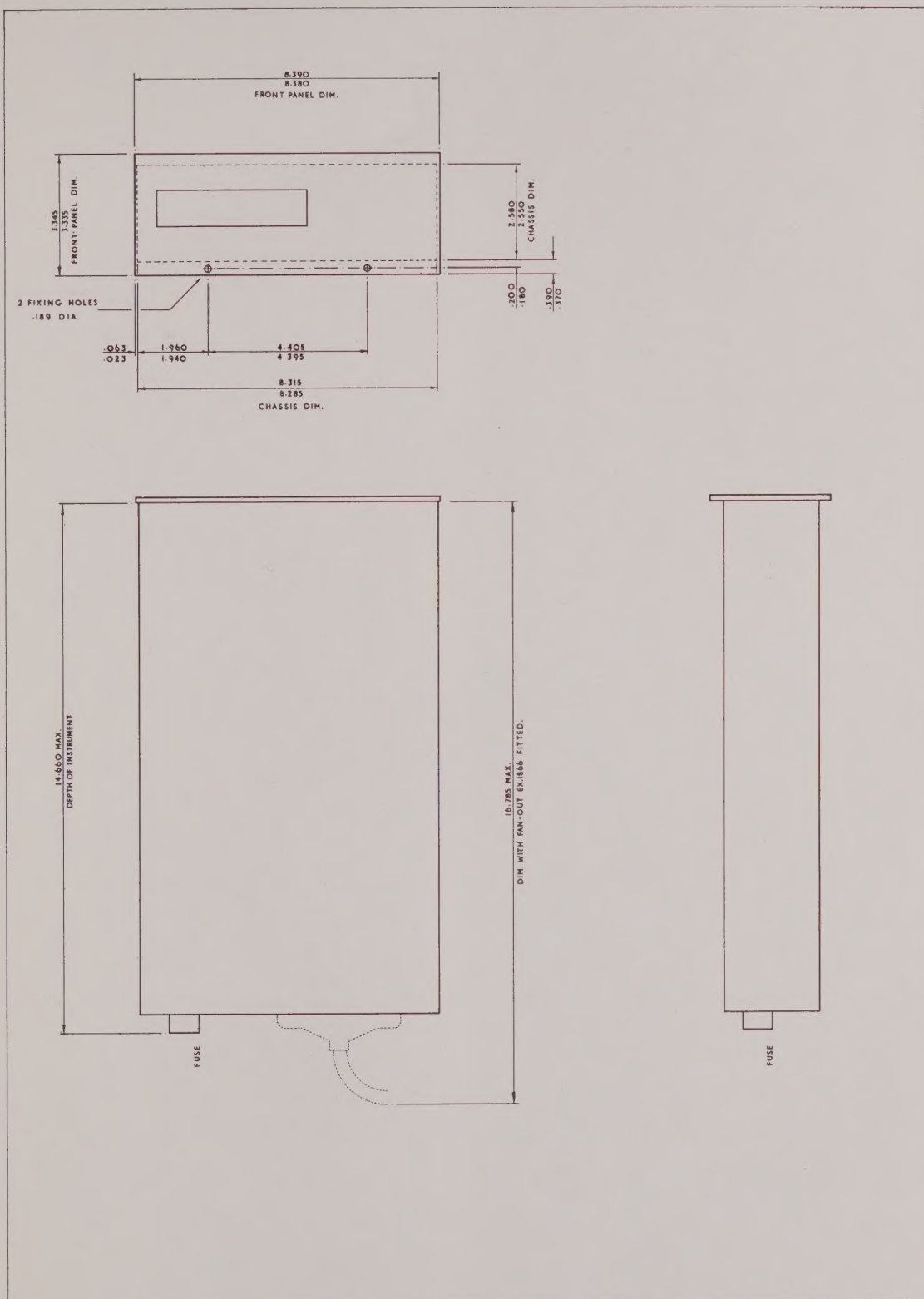


Diagram 1 LM1620 Dimensions for Rack Mounting.

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